NPS - 62Ja77031

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

ELECTRONIC WARFARE SIMULATION AS APPLIED TO
PASSIVE INTERCEPT TRAINING

Normand Arthur Houle

March 1977

Thesis Advisor: S. Jauregui

Approved for public release; distribution unlimited.

Prepared for:
Naval Electronic Systems Command (PME-107)
Washington, D.C. 20360

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER NPS - 62Ja77031	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ELECTRONIC WARFARE SIMULATION AS APPLIED TO PASSIVE INTERCEPT TRAINING		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; (March 1977) 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Normand Arthur Houle		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Electronic Systems Command (PME-107) Washington, D.C. 20360		12. REPORT DATE March 1977 13. NUMBER OF PAGES 98
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electronic Warfare; Simulation; Stimulation; Intercept; Passive Intercept; Training; Electronic Support Measures

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Elements of simulation in general and of electronic warfare (EW) in particular are presented. In the area of EW simulation, radio frequency (RF) stimulation is emphasized. A survey of four current or proposed EW simulators is presented in Section V: 7B1/1 Stimulator; Naval Electronic Warfare Training System, Device 10H1 (NEWTS); 10A3/1,2,3 Stimulators; ELINT/COMINT Receiver Test Systems. Finally, desirable features to look for in an EW simulator are discussed.

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral Isham Linder
Superintendent

Jack R. Borsting
Provost

This thesis prepared in conjunction with research supported by Naval Electronic Systems Command (PME-107).

ELECTRONIC WARFARE SIMULATION AS APPLIED TO PASSIVE INTERCEPT TRAINING

by

Normand Arthur Houle
Lieutenant, United States Navy
B.A., St. Anselm's College, 1969

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL

March 1977

ABSTRACT

Elements of simulation in general and of electronic warfare (EW) in particular are presented. In the area of EW simulation, radio frequency (RF) stimulation is emphasized. A survey of four current or proposed EW simulators is presented in Section V: 7B1/1 Stimulator; Naval Electronic Warfare Training System, Device 10H1 (NEWTS); 10A3/1,2,3 Stimulators; ELINT/COMINT Receiver Test Systems. Finally, desirable features to look for in an EW simulator are discussed.

TABLE OF CONTENTS

LIST OF FIGURES

I. INTRODUCTION

To date, much of what has been written about the art of simulation, has been simulation vis-a-vis control system theory and application. The study of man-machine relationships probably received its greatest impetus in the space program of the 1960's under the sponsorship of the National Aeronautics and Space Administration. Only recently have Department of Defense agencies, in the Navy notably the Naval Electronics Systems Command, the Naval Security Group Command, the Naval Research Lab, and the Chief of Naval Education and Training, taken a close look at the role of simulation in the design and use of passive intercept systems. The prime reason for the surge of interest is probably financial. The Navy cannot afford to train people at sea because of the high cost of deploying units, or, equally important, do exhaustive testing of one complex intercept system prototype before commitment to force-wide installation. These new systems cost too much money for that sort of luxury test, and delaying procurement decisions greatly aggravates the situation.

The purpose of this paper is to bring together some of the various sources found in texts and government reports concerned with simulation in general, and man-machine simulation in particular (Sections II through IV). Interspersed throughout this discussion will be where and how simulation can play a vital role in the realm of passive intercept. "Passive intercept" as used in this paper primarily denotes the intercept of electromagnetic radiation with no response by the interceptor. Active actions such as jamming are therefore excluded. Later in the paper (Section V) descriptions of four simulation systems will be presented

with comments concerning their projected or actual performance. Finally, there will be an examination of some of the more important features one might desire in an electromagnetic environment simulator.

II. WHAT IS SIMULATION?

A. INTRODUCTION

As used in system engineering, the word simulation refers to the construction of a representation of a process or system in order to facilitate its analysis. It is characterized by the fact that it does not include all the features and characteristics of the original system or process.[1]

In the realm of electronic warfare (EW), several definitions have evolved which may be confusing to the uninitiated. It would be appropriate to examine these at the outset if only to become familiar with some of the jargon one is bound to encounter.

"Stimulation" is a simulation technique wherein signals are presented to various tactical equipments as RF inputs at the antenna entry ports.

"Video simulation," or sometimes just plain "simulation," is a technique wherein signals are provided in video or audio format (either digital or analog) to the front panels (real or simulated) of the tactical equipment. This design bypasses most or all of the tactical equipment itself.

In "hybrid" design, signals are presented at either RF, IF, or video/audio (digital or analog) as appropriate for each specific tactical equipment. The signals are generally

provided at a convenient and common point within the tactical equipment, where frequencies are up or downconverted to common (usually IF) frequencies. Hybrid bypasses some elements of the tactical equipment.

B. MAN-MACHINE SIMULATION

The introductory definitions just presented do not specifically take into account the human element of simulation, one which should be examined in a study of passive intercept systems. Therefore, let us consider some of the elements of man-machine simulation.

Man-machine simulation is defined as the provision of a device or devices to represent a system with varying degrees of realism, including the details of the environment in which the system operates.[2] On the surface, this is a rather straightforward definition, but it has many facets worth examining.

Although 1984 may be just around the corner it is difficult to believe that all decision making processes will be handled by machines. Even in increasingly automated systems, men will continue to play an active and vital role. But as system requirements become more demanding, it becomes increasingly important to consider the allocation of functions to men and machines early in the design process so as to maximize the contributions of each to overall system performance. In order to take advantage of man's potential contributions as a system component, the engineer must have an appreciation of man's capabilities, and of the design limits which might be imposed by them.

Bekey and Gerlough [1] list characteristics particular to manned simulation, some of which will be examined later

but in sum are presented here. Simulation involving man includes all the characteristics of unmanned simulation, with the following additional ones introduced by the particular characteristics of human performance:

1. Human performance is inherently variable. There is a variation of successive trials of the same task by the same operator, and there is a variation in the responses of several operators trying the same task.

2. Human response includes elements which are apparently not determined by the input and can be accounted for only by statistical descriptions. Consequently, the description cf systems involving human operators must make use of statistical methods, and the resulting descriptions will be in some sense statistical averages defined over particular populations.

3. The inherent variability of human performance implies that many repetitions of each particular experiment must be tried.

4. Simulation studies involving human operators must be run in real time, whereas studies involving inorganic elements may be run in an accelerated time scale in many cases.

5. The simulation method and the experimental situation must be selected in such a way as to avoid any possible injury to the operators involved.

In view of the statistical nature of man in this context of simulation and the requirement to run simulations at real instead of accelerated time, some researchers have made attempts at formulating mathematical models of man. Skolnik, in his authoritative textbook <u>Introduction to Radar</u>

Systems, discusses a radar operator efficiency factor in the context of probability of detection of a radar target. Others have tried to model man in some linear and quasi-linear fashions as a transfer function in a tracking control loop. With very simple operations they have met with limited success, but they apparently are still a long way from effective and accurate modeling of such a complex entity as man.

One of the limitations imposed by man's presence in a control system is his limited information bandwidth. Skolnik has it listed on the order of 10 Hz/20 bits per second. Needless to say, the rates at which information can be provided to man would simply overwhelm him. Therefore, one should consider, especially in a passive intercept system, the incorporation of automatic preprocessing of incoming signals. For example, such preprocessing might be programmed to disregard unwanted signals, or signals already noted and analyzed which are of no further value; to make recordings on signals of interest for which there is no urgent need of immediate operator attention/analysis, or which are too complex for rudimentary analysis at a remote intercept position. By filtering out signals such as these, the operator is left with more time to devote to important signals of tactical interest.

The definition of man-machine simulation addressed the representation of a system with varying degrees of realism, including details of the environment in which the system operates. These two areas, "degree of realism" and "details of the environment," will be specifically addressed in Section IV, "Characteristics/Methods of Simulation," but it might be well at this time to note the "environment" faced by the EW specialist. "Environment" in this context means the signal environment.

The growth of EW in the last decade has been just short of phenomenal. Largely because of our involvement in the Vietnamese War, force commanders have come to appreciate the worth of officers and men knowledgeable in the art of EW. Prior to the Southeast-Asian conflict, EW was of lesser importance. Signals of hostile intent to our strategic forces were of course noted and analyzed, but little was done in the area of tactical conflict. However, with the advent of Vietnam and the introduction of sophisticated Soviet weaponry, we were faced with the grim reality of increasing losses to our aircraft inventory. Being able to recognize and counter enemy threats through the use of "black boxes" became immediately important to pilots and is still today of vital importance to the military.

Theoretically, one could probably build a black box for each system to be countered, but that is neither realistic nor necessary. While it is true that certain parameteric measurements can more rapidly and accurately be accomplished by machine, man still ranks high as a correlator of information and decision maker. And the man who is most often the first to come face to face with an enemy threat is the EW specialist. If he is to analyze and react to today's swift and sophisticated weapons system, the equipment he uses and the level of his expertise must at least match the level of sophistication of those systems he must face. So how so you train him to cope? You might place him in a live environment. This is very realistic, but not very practical as the expense in time and money incurred to achieve a proficiency which can only come from repetitive exercise would be excessive. The only viable alternative seems to be simulation. There are today tried and proven equipments which can replicate just about any signal imaginable and in realistic densities. You can thus provide the needed realism and repetitive trials with a somewhat greater assurance that if your operator can handle this simulated

environment, he will be better prepared to deal with a real environment later on.

C. LIMITATIONS OF SIMULATION

In spite of all the great things that simulation might be able to accomplish, it does have limitations. Possibly the greatest limitation is the inability of simulation to achieve total realism. Only at great expense may one be able to closely approach the real system or real environment. But the necessity for this high degree of realism must be weighed against the costs, and still the fidelity of the system should be closely scrutinized.

The validity of test results must always be questioned. In a simulation test, one usually seeks to verify a particular aspect of a problem or behavior. One must be cautious about formulating a picture of a total system performance based on isolated component tests: simple linear superposition to achieve a composite view of a system's performance, or of man's performance in the system may not necessarily be a valid assumption.

III. WHY SIMULATE?

A. SIMULATION AND DESIGN

The importance of simulation in systems engineering arises from the fact that simulation makes possible the verification of proposed designs before completion of the system development, thus resulting in valuable savings of time and money. If basic design knowledge in a new area is nonexistent or at best weak and limited, simulation can provide the means for preliminary testing and evaluation of alternative designs before commitment to a specific one. In fact, to a great extent today, much design work is being accomplished through hands-on interaction between the engineer and a computer working with a mathematical model, whose validity is considered high. This technique can immediately provide the effects of changes in design parameters. It is often a trial-and-error method of reaching an acceptable solution, but it works.

In a system where a human being performs a control function, some form of simulation should be conducted in the design phase. Very often something as simple as a cardboard mock-up of a system can prove to be valuable in determining or ascertaining the position of needed controls and displays. Such a mock-up was constructed for the relocation of equipment of an AN/WLR-6 receiver system. The front panels of all equipments were recreated on cardboard, the dimensions of the installation appropriately layed out, and operators invited to "move the equipment around" so to speak, to achieve the optimum layout for them, rather than

for a design engineer. One step up from the cardboard mock-up to provide an increased degree of realism is to have functional front panels with computer-simulated audio and/or video inputs; of course, costs increase substantially.

B. SIMULATION FOR TESTING

The discussion above related how simulation could prove valuable in the evaluation of individual component design and performance. That situation can be easily turned around and the simulation applied to the broader and more comprehensive aspect of systems testing. Recall the cautionary note on formulation of a picture of the total system operation based on the testing of isolated components: simple linear superposition to achieve a composite view of performance may not be a valid assumption. One of the key uses of simulation is the evaluation of the effect various elements of a system have upon each other and upon the performance of the system as a whole.[1]

C. SIMULATION FOR CONTROLLED REPEATABILITY

The ability of simulators to repeatedly and precisely perform a programmed sequence of events is particularly valuable in two areas: the evaluation and training of operators, and the study of sources of system failure. Simulation is particularly advantageous in pinpointing the cause of a system failure. Without this controlled repeatability of tests, environments, or scenarios, it would be very difficult, if not impossible in many cases, to determine sources of failure or instability.

D. SIMULATICN AND CONTROL OF COSTS

Clearly an important part of simulation is the attempt to reduce overall costs. The usefulness of simulation for evaluation of alternative designs has already been mentioned and the resultant savings of the approach should be obvious. The mammoth cost of new large-scale, and complex systems (this certainly describes recent and proposed intercept systems) requires that contractors and users resort to simulation. One cannot afford the risk of multi-million dollar failure that goes with a system design philosophy wherein one copy is built and then tested for satisfactory performance. The risk is too great and the time lost by such an approach is significant. Simulation must become an integral part of a system's evolution from inception to production. We are today beginning to see the introduction of new systems wherein the decision to proceed with full scale production has to be made before the initial copy is operationally tested. Cost conscious budget men dictate it, and the need for up to date, rather than outmoded-before-operational, intercept systems requires it.

Besides this design aspect of costs, the general unavailability of operational systems for the training and testing of operators enters the monetary picture. An operational intercept system requiring the use of its host platform for training purposes is no longer feasible in this era of high fuel costs. Realistically speaking, simulation is the only answer. And we may be surprised to find just how realistically an operational electromagnetic environment can be created with today's EW simulators. This will be dealt with to some extent later on, but for now suffice it to say that almost any type of signal can be duplicated, and

sufficient numbers of them can be generated to present realistic signal densities to the intercept operator.

E. SIMULATICN FOR TRAINING

M.A. Grodsky [3], in his examination of simulation vis-a-vis our astronaut training programs has made some interesting observations which should be applicable to any man-machine system. He writes:

> "The importance of considering simulation relative to operator performance can be viewed in the light of the following factors:
>
> "1. The assessment of operator performance in any man-machine system is the precursor to the final definition of man's role in the system, the flexibility and effectiveness of the system, and the general requirements necessary for the support of the man. In order to provide a completely effective man-machine system, man's role must be clearly specified in quantitative terms.
>
> "2. The assessment of operator performance is a complex problem in which little operational data is available. Simulation is one of the techniques by which applicable data in sufficient quantities and under controlled conditions can be collected.
>
> "3. The assessment of complex operator performance appears to best focus attention upon the advantages and disadvantages of simulation as well as some of its future requirements and fidelity problems upon simulation."

He also presents a table listing various uses of simulation. Again it is written in the light of astronaut training, but should also apply in general to training of intercept operators. Simulation can be helpful in the evaluation of operator capacities: in determining physiological and psychological limitations in normal operating conditions and under stress; in determining the performance and proficiency of man-machine systems in normal operating conditions and under stress; and in predicting operator performance under stress. Simulation can be valuable in the study of procedures and requirements: in the allocation of function to man and machine; in the determination of personnel requirements; in the

determination of operating procedures; in the determination of maintenance procedures and logistic support requirements; and in the determination of work schedules. And, simulation is an important tool in the actual selection of operators; in the development of training programs, devices and standards; in the determination of special training; for initial training of new operators and proficiency training for seasoned veterans; and for the prediction and measurement of proficiency.

Simulation might prove quite valuable in the selection of intercept operators and their assignment to particular intercept teams. How the individual man relates to his simulated working environment could be observed, and in those instances when he is found to be unsuited or not quite ready to assume his duties, or when personality clashes preclude the harmonious relationship necessary for efficient team function, he could be reassigned elsewhere. One does not always have the luxury of a large pool of operators to choose from, but when one does, this sort of test could help reduce the incidence or severity of friction among deployed team members.

IV. CHARACTERISTICS/METHODS OF SIMULATION

A. INTRODUCTION

Simulation equipments and methods may be characterized in various ways, and discussed from many different points of view. In this section, simulation will be examined with regard to: degree of abstraction (physical vs. mathematical simulation); characteristics of manned simulators; computers and simulation; and finally, signal generation for EW simulators.

B. DEGREE OF ABSTRACTION

The process of simulating a real system, in and of itself must involve abstractions of the real world environment. These abstractions may be of varying degrees of severity. For example, a scale model, truly to scale, and properly instrumented so that instruments do not alter the model significantly, is not a severe departure from reality. Analogous models, such as the representation of large mechanical systems by relatively small electrical components, is a more serious departure; although the analogies may be warranted and valid, electrical components may not react exactly as the mechanical elements they represent, and scaling (both time and frequency) becomes more difficult. Finally, a much more severe degree of abstraction results when representing a system completely through the use of mathematical equations. It would be virtually impossible to totally describe anything but the

simplest of systems in terms of mathematics. And as system complexity increases, so does the size of the computers needed to accomplish the desired mathematical computations. So we see here two basic simulation strategies: physical simulation (like the scale model and even the electrical analog) wherein a physical system is simulated by the construction of another physical system which obeys the same or similar laws as the original system; and mathematical simulation, wherein the simulation is based on the solution of equations which describe the performance of a system.

Bekey and Gerlough [1] present a clear and concise comparison of physical and mathematical simulation:

* Mathematical simulation is characterized by the following:
  - Easy parameter variations
  - Mathematical description required of all system elements
  - Time scale can be varied by selection of computer components
  - Well suited to fast-time simulation
  - Results affected by selection of model and quality of computer components
  - Possibility of false solutions due to the characteristics of the equations themselves.

* Physical simulation on the other hand is characterized as follows:
  - Parameter variations may be difficult
  - Mathematical description not required of all system elements
  - Generally designed for a fixed time scale
  - Well suited to real-time simulation with human operators
  - Results affected by selection of model and validity of analog

- No possibility of false solutions due to the characteristics of the equations themselves.

The mathematical simulation seems to be more versatile since parameter variation or alteration of the system structure would be more convenient. On the other hand, a mathematical model for each system element must be formulated. And when venturing into new areas, or areas of severe complexity, or when statistical variability must be taken into consideration (as when human behavior/response is part of the problem), systems may defy mathematical definition and force the incorporation of physical elements.

For every two-sided argument, there seems to be a middle-of-the-road position possible and so in this physical/mathematical comparison, Bekey and Gerlough have come up with the "partial-system test." This is described as the interconnection of a physical element with a general purpose computer which represents a mathematical analog of the rest of the system. This type of simulation is employed primarily in two sets of circumstances: when a mathematical description of an element is unavailable or difficult to formulate; or when the performance of the system element must be evaluated under conditions which simulate actual system performance, but the rest of the system does not yet exist or may be too difficult or expensive to use. Caution must be exhibited when conducting partial-system tests. A good understanding of the effects of the dynamics of the interconnection between computer and physical component is essential, and the test is inherently limited to particular aspects of the total system and/or the total environment of the completed system so that care must be exercised in drawing conclusions on total system performance (recall, that linear superposition may not apply).

It will be found that many of today's EW simulators are characteristically both mathematical and physical in nature. They are physical simulations in that they receive and analyze real or synthesized electromagnetic signals often through the use of the actual intercept equipment found on intercept platforms. They are mathematical simulations particularly when they incorporate the relative movement of targets and intercept platforms on some hypothetical "field of play." The CRT display of unit position, the relative changes in electromagnetic signal strength and signal direction injected into intercept receivers and direction finding equipment is all accomplished via the solution of mathematical equations describing electromagnetic propagation and positional geometries.

More might be said on the formulation of models for mathematical simulation.[1] The construction of a model is based on information obtained from the physical world by observation or measurement. Consequently, measurement errors will result in erroneous models. Furthermore, measurement is often corrupted by noise; it is characterized by the fact that it is never exactly repeatable either because the process itself is subject to random variation in time (you cannot reproduce exactly the whole of the electromagnetic environment) or because the measurement includes some random variability, or both. Consequently, one of the serious problems in the simulation of a process is the selection of those random elements which one desires to incorporate in the model. Many models are constructed on a purely deterministic basis with the understanding that the results obained from the models may represent statistical averages of certain variables in the physical systems. In many problems, the random nature of certain variables or the presence of random disturbances represents an important aspect of the system. In such cases, the simulation will

include ncise sources, and Monte Carlo techniques (described briefly below) may be used to determine satisfactory confidence limits on the system response.

The Monte Carlo method provides a way for numerically treating problems involving random variables. Statistical results are obtained by repetitive sampling procedures from a given probability distribution. The probability that the results of the computation will be within a given interval of the theoretical results is a function of the size of the sample.

C. ELEMENTS OF MANNED SIMULATOR SYSTEMS DESIGN

In this section, three elements of manned simulation will be addressed: simulation techniques in the assessment of operator performance; design of displays and alarms; and system characteristics of man.

1. Manned Simulation Techniques

Various types cf manned simulation techniques have been tried to assess operator performance. Grodsky[2] has outlined several of them:

1. Mockups

* soft mockup: a cardboard paper display layout with no actual hardware or functional considerations (this is the type alluded to in the AN/WLR-6 redesign)
* hard mockup: an actual three dimensional layout of the man-machine interface, usually without functional components
* functional mockup: a hard mockup with a design layout of actual or prototype equipment and with some

function associated with the man-machine interface of the equipment.

2. Engineering or scientific judgment: the use of expert opinion or available data in the literature which is subjected to mathematical or quasi-mathematical procedures in order to assess complex performance.

3. Laboratory or synthetic task techniques: the use of psychophysiological test situations or test batteries which are constructed to test various specific behavior domains or to evaluate generalized performance or behavior associated with various systems.

4. Dynamic simulation: the dynamic reproduction of complete or various portions of a man-machine system with various degrees of fidelity; this technique can be divided into partial task or full scale mission simulation.

5. Operational evaluation: the actual operational evaluation of operator performance on the real system itself.

Of these five types, the functional mockup and dynamic simulation techniques are noteworthy. The operational evaluation is of course the most realistic, but also the most expensive. The technique deemed most valuable is that of dynamic simulation. Both quantitative and qualitative data on system performance can be obtained, as well as a very realistic and critical appraisal of an individual's or team's performance. In this respect, the dynamic simulator is the next best thing to the actual system itself.

2. Displays and Alarms

Not only should displays be visible and legible to the operator, but they should also be the best suited for the function intended. For example, if you wanted to observe the relative position of a number of frequencies within a given band, a panoramic display would be most appropriate, but if you wanted to know the frequency of each of those signals, a digital readout system would be considerably more appropriate. The design of displays for wideranging system monitoring must go one step further and consider the interdependence of individual meters and the fact that the operator will effectively be sampling/multiplexing various displays sequentially. Pew[3] relates how it takes time for an individual to shift attention from one display to another, and that one of the purposes of an integrated display system is to minimize the time it takes to read in information from a great number of displays. Also, interpretability is enhanced by reducing the recoding requirement on individual displays; for example, trying to minimize the abruptness between say analog and digital reaouts or between two different types of analog metering systems.

Particular attention must be paid to the design of alarms. Audible alarms in a quiet environment probably are more effective than visual ones (but the intercept operator is not always priviliged to work in a quiet environment; the perpetual hum of cooling equipment can be deafening), but visual ones must be restricted to what may be a limited field of view, that is, the display/control panel which will more than likely already be lighted by a not insignificant number of dials. Some intercept equipments incorporate both aural and visual alarms.

3. Characteristics of Man the Processor

It is man's ability to process information, that is, take it in, manipulate it, compare it to previously processed/stored data, then decide and act on it, that makes him a desirable part of a system.[3] A few observations can be made on man's effectiveness as a processor. On the input side, man is like a scanner or filter of limited bandwidth, so that new data can only be fed to him at limited data rates. Therefore, as much automatic machine prescanning as possible, without minimizing or severly degrading the basic information needed for a decision process should be incorporated in a high data rate system. Certain intellectual operations involve information compression. An operator combines information from a variety of sources and reflects it in a single output operation or decision; the more compression required, the slower the processing. Compression for the human operator is equivalent to data reduction for a computer. The more data reduction a computer can accomplish, the less need be done by man, freeing him to concentrate on the most important and most qualitative aspect of processing, that of decision making. But even this decision making aspect is being intensely studied by researchers. Mathematical models of rational decision processes are available and we seem to be headed in the direction of computer-made decisions with man acting only as an evaluator of that decision.

D. THE ROLE OF COMPUTERS IN SIMULATION

The sheer complexity of large scale systems, along with the vastness of the electromagnetic spectrum, necessitates the use of computers. This section will be devoted to a discussion of the two basic types of computer simulation,

analog and digital. The actual incorporation of computers into the simulation schemes will be presented later in conjunction with particular system overviews.

When a simulation is characterized by continuous signals, it is called analog simulation. Although it should be applicable to both mathematical and physical simulation, analog is usually associated with the latter. For example, simulation of manual attitude control of an aircraft would probably be an analog type function, just as the constant readjustment or "fine tuning" of the steering wheel of an automobile moving along a "straight" path is an analog function. Moreover, if you look back at the earlier comparison made between physical and mathematical simulation, although you could associate some of the mathematical characteristics with analog simulation, the physical ones seem to predominate. All of this notwithstanding, today one would have to say that the analog computer has taken a definite back seat to digital equipments, if only to accomodate ever more powerful digital computers. When analog signals are necessary or appropriate, high speed digital to analog converters perform as well as pure analog elements.

When simulation consists of the manipulation of phenomena which occur with discrete values, it is referred to as digital simulation. Whereas analog techniques seemed to be more akin to physical simulation, digital ones are more closely associated with mathematical simulation. Any system which can be represented by a set of equations is a natural for digital simulation. This is not to say that it is restricted to this area; high speed analog to digital conversion effectively allows the application of digital simulation techniques to continuous analog processes.

The marriage of digital and analog techniques into what are called hybrid systems should be obvious. Digital/analog conversion equipment has already been mentioned. The advantages offered in bringing these two together are as follows [1]: The analog equipment lends itself readily to simulating that portion of the system which includes high frequencies, complex nonlinearities, and/or physical elements of considerable variability in measured characteristics; whereas, elements involving requirements for high-accuracy, drift-free computation and complex decision functions are ideally suited for simulation by a digital computer.

E. SIGNAL GENERATION TECHNIQUES IN EW SIMULATION

Up to now, this paper has discussed simulation in a rather broad and academic sense. In this section will be discussed some of the techniques that have been used in the generation of signals for EW simulators. The largest portion, however, will be devoted to a discussion of low power RF signal generation, as this technique seems to be one of the more widely accepted ones.

There are basically three broad categories of signal generation:

1. RF Stimulation, which can be of two very different types:

* Electromagnetic signals are generated at RF and actually transmitted through space utilizing the necessary power amplifying stages, and the transmitting and receiving antennas. Implicit in this technique is the use of actual signal transmitters.

* Electromagnetic signals are generated a RF but at

low power. The transmission "medium" is basically a cable or waveguide running from the output port of the signal generating equipment, to the input port of the intercept system. High powered amplifiers and antennas are not needed.

2. IF Stimulation: This is basically the the same as low power RF stimulation but signals are generated and "intercepted" at the intermediate frequencies. The "front end" (RF amplifiers and heterodyning mixers) is thereby bypassed in the receiving equipment.

3. Video Simulation: In this technique, synthetically (usually computer) derived static or dynamic displays effectively produce a replica of operational displays (e.g. radar targets on a PPI scope). If the IF stimulation is seen to bypass the RF stages of a receiver, this technique bypasses both RF and IF stages, producing only a synthetic display. One might include an audio track along with the video; for example, letting an operator hear a radar as it "scans" (which can be experienced visually on a synthetically driven PPI scope) by the target platform.

The video technique, though relegated to the third position in the above listing, has very useful applications. If the prime intent of your trainer is to teach operators to recognize by sight or sound a particular type of signal; or if you seek to train/evaluate a technician on <u>data</u> analysis (vice data and <u>signal</u> analysis) or evaluation techniques, there may be no real need to actually intercept an electromagnetic signal, be it at RF or IF. The sophisticated intercept systems of the future will be highly automated. Most of the signal parameter analysis and recording, as well as some rudimentary decision making (e.g. deciding via predetermined program algorithms that a particular type of modulation on a particular frequency is

or is not of tactical interest), will be managed by computers. Under these circumstances, the intercept operator will be presented with digested data upon which he must act. The display panel will be the primary focal point in such systems, and the ability of an operator to interact with his display is a skill for which he must be trained and must be tested. When the training problem is examined from this unique point of view, the need for actual signal generation is considerably lessened if not totally eliminated.

On the other hand, unless you are going to go through the trouble of deliberately corrupting your displays with noise, the video technique is apt to provide very antiseptic signal displays. This is not "real world" and trainees need to be cautioned about some false sense of excellence in performing signal analysis/measurements on such clean signals. This method may not even afford the capability of performing parameter measurements in the sense of injecting a signal into a frequency meter or PRF analyzer as is still extensively done today by operators in the field. Finally, computer driven displays may require a considerable amount of software development; this is a very expensive proposition.

The IF technique will not be discussed to any great extent because it is like the low power RF method, only at intermediate rather than radio frequency. The advantage of this method lies in the elimination of RF stages and the monetary savings this entails. Note however, that tuning and gain control manipulation are lost. In the implementation of this technique, one should keep in mind that intermediate frequencies are not necessarily the same for all receivers. Two alternatives are possible: First, the stimulator could provide various IF output ports, but the manufacturer who already produces RF generators will

have to modify his equipment. What is saved in eliminating front end circuitry will have to pay for the equipment modification. Second, the manufacturer might provide only one IF output port, which would have to be heterodyned to the needed IF of the receiver, and all that has been gained is the elimination of the RF amplification stage. It may not be worth all the trouble. With the IF technique some of the distortion inherent in the front end of receivers is also lost. IF stages are quieter and more stable so that the realism included when RF stages are present is very much diminished. Again, but to a lesser extent than with video simulation, operators may be lulled into a false sense of expertise in the area of signal analysis technique.

The powered RF technique is less attractive than the low power technique for several reasons. Although it is realistic (it is the actual signal transmitter), it would require the incorporation of antennas in the simulation scheme as opposed to simple coaxial cable or waveguide between stimulator output and receiver input ports. It would also be very expensive to buy and maintain. But this is not to imply that the technique is totally without merit. One can site a specialized application such as the ECM Environment Simulator (ECES) System at the Naval Air Development Center in Johnsville, Pennsylvania. Its purpose is to determine the susceptibility of a radar in an environment of different types of ECM under a wide range of conditions. Testing is done at RF with the actual radar and a jammer "facing-off" so to speak, in order to evaluate the radar's ECM vulnerability. This may not be just the best way of conducting such a test, but also the only way for obtaining valid performance data. So, powered RF stimulation does have applications, but it does not appear to be very appropriate in the area of passive intercept.

Before proceeding on to the low power RF methods, a hybrid low power/powered technique has been proposed as a possibility by at least one manufacturer wherein varied signal generation is first accomplished at low power, then fed to a powered stage for transmission. This affords the possibility of testing receiving antennas on board the intercept platform as well as the intercept suite itself. It also takes into account propagation effects because of transmission through the atmosphere, whereas other methods do not always do so.

Having noted the shortcomings of the other systems, relative to the low power RF system, one should have a fairly easy time of listing some of the characteristics/advantages of this final technique, namely low power RF signal generation. What we have here are small scale models replicating the actual transmitters. Recall how earlier in this paper scale modeling was included as a method of simulation; but whereas scaling was apt to be in general a critical procedure in the simulation design, it does not appear to be too serious here as signal generation even for powered transmission begins at low power anyway. Implied here is the possibility of very accurately replicating the model emitter. The techniques for generating most signals are fairly well understood. Doing this on a small scale is little more than utilizing the processes of an actual full scale system. The significant difference of course, is the desirability of the model generator to have the flexibility to generate many different type signals.

The prime advantage to RF stimulation is well stated by J. DiGiovanni: "The importance of RF emitter simulation stems from the fact that seemingly minor variations in emitter characteristics will cause noticeably different

responses in various EW receivers. As a result, accurate recreation of emitter parameters is of major importance and critically affects the realism of the receiver display and audio signals supplied to the operator."[4] Whereas in the other techniques the "front end" stages were either bypassed or eliminated altogether, in this method they are retained along with all the inherent peculiarities and distortions they impress on an incoming signal. This is the normal result of imperfect (and unrealizable) components. So if one's goal is to provide the EW trainee with the most realistic environment possible, this technique will go a long way in providing the qualitative aspect of noise and distortion. It could be noted here that the final degree of realism it will not provide is the signal modification which results from the propagating medium. The vagaries of this phenomenon are so complex and fickle that one may simply have to sacrifice this degree of realism. Nevertheless, this may not necessarily be totally impossible. The Naval Electronic Warfare Training System (NEWTS) which will be presented in the following section, at least takes into account the topography of a gaming area so that one is prevented for example, from transmitting directly through mountains; that is, the effects of the geography are programmed into the signal generation. In any case, the distortions resulting from signal processing will probably be sufficient. Retention of the "front end" also allows the operator to perform those manual RF tuning and gain functions associated with this segment of the receiving equipment. In view of this fact, this technique provides the possible utilization of the actual intercept equipment the trainee will find in the field, an important factor where on-the-job training is either too costly in terms of manhours lost, impractical, or impossible to implement.

Other advantages this RF technique can include: placement of several of these emitter models under control of a computer to create a more complex and dynamic electromagnetic environment; broader application to test, evaluation and maintenance programs; relatively straightforward interface between stimulator and different intercept systems (one would not expect radical modifications from one equipment to the next); electromagnetic interference (EMI) problems are reduced - by using lower power, less shielding is required; by introducing signals directly at signal ports, the security problems associated with simulation systems using actual transmitters is reduced.

The remainder of this discussion will examine some of the basic technical aspects associated with the low power RF technique. The basic RF environment simulator concept employs a small scale electronic model of the actual RF emitter, wherein the RF signal is modulated by an appropriate pulse train, and the complex antenna scan patterns are electronically superimposed on the output signal by a scan pattern generator.[4] We see therefore that three of the more general and most important signal parameters are: RF frequency (40 GHz is the most common upper limit), antenna scan characteristics, and pulse train characteristics. A more detailed list of parameters, so broad in scope yet specific in detail that computer control becomes necessary, might include:

1. RF frequency

2. scan type

3. scan rate

4. main and sidelobe structure

5. pulse width

6. pulse repetition frequency

7. peculiar pulse coding/modulation, for example:
   * pulse jitter/stagger
   * pulse sliding
   * frequency agility
   * chirp
   * intrapulse modulation

8. initial power level

9. subsequent parameter changes if required

To achieve a high signal density electromagnetic environment, one could use a very large number of generators or more sensibly, time division multiplex a number of signals. The sampling theorem states that a signal sampled at a frequency that is at least twice its bandwidth is completely recoverable. With a number of signals, sampling is done at a rate associated with the signal of greatest bandwidth. Antekna, Inc. points out the possibility of pulse drop out with this technique; however, they have managed to minimize this effect (to less than 1% on a statistical basis). Nevertheless, there may be instances where even this low level of pulse drop out is unacceptable, as in specialized or high-powered signals, or telemetry signals, thus precluding the use of multiplexed pulse trains.

Finally, a few words on methods and maintenance of accurate frequency generation are in order. Primary methods of generation include: YIG-tuned (Yttrium Iron Garnet)

oscillators; varactor/tuned oscillators and fixed cavity oscillators. The last of these methods has the limitation of being fixed to the one resonant frequency of the cavity, and even if it were mechanically tunable, both tuning rate and accuracy would probably be unacceptable. Antekna ran a series of tests between YIG and varactor-tuned oscillators to study their frequency accuracy and stability. The varactor-tuned oscillator's fast tuning ability was found to impact on the stability at any individual frequency. on the other hand, the YIG-tuned oscillator was able to meet stringent requirements because of low drift characteristics and low spurious signal generation.

V. ELECTRONIC WARFARE SIMULATORS - AN OVERVIEW

In this section, four electronic warfare simulators currently in the inventory or on the drawing boards for delivery in the near future will be outlined: the Antekna 7B1/1 Stimulator at Groton, Conn. and 10A3/1/2/3 Stimulators at Corry Station, Pensacola, Florida; the Grumman Naval Electronic Warfare Training System (NEWTS) also at Corry Station; and finally the COMINT/ELINT Receiver Test Systems (CRTS/ERTS) in San Diego. The intent is to make the reader not only aware of their existence, but to also show how they realize some of the characteristics of EW simulators enumerated in other sections of this thesis.

A. 7B1/1 STIMULATOR

This device is an RF EW environmental training system. Two units have been manufactured by Antekna, Inc. one of which is located at Pearl Harbor, Hawaii, and the other at Groton, Conn. It employs a small scale model of each emitter to produce a realistic replica of the RF environment, which in turn is fed to one of four receiver systems. The stimulator's output represents 18 maneuverable RF (radar type) emitters and 16 non-maneuverable communications emitters. Except for front panel control settings of ancillary devices and communications channels, magnetic tape inputs to ancillary devices, and patch panel connectors, operation of the stimulator can be computer-controlled during the period of a simulated mission. Under computer control, the stimulator produces a mission in real-time by simulating changes in range and bearing of the maneuverable platforms and the observer's own ship. Fixed targets can be

generated through front panel controls on the emitter modules. A mission can be interrupted at any desired time, and then continued or restarted under computer control. Modifications to a prepunched (input is via paper tape) scenario can only be accomplished with the system halted, i.e., either before initiation at time 0000 or during some interrupt period; it cannot be modified during actual program execution. After the scenario has been entered into computer storage, the mission may be run (maximum duration: 2 hours), or a paper tape of the program may be punched as output for library storage.

The major functional portions (see Figure 1) of the system are:

1. computation/control center

2. emitters

3. ancillary devices

4. stimulator/receiver interfaces.

The equipment is housed in seven racks and one free-standing teletypewriter unit.

1. The Computation/Control Center (CCC). The multiplicity of emitters represented in the system, each with parameters which can be varied from time to time, requires that the major part of the system be automatically controlled. In the 7B1/1 this is accomplished by the CCC. Its components consist of an Hewlett Packard (HP) Model 2100A computer, Model KSR 37 teletypewriter, HP Model 2753A Paper Tape Punch, HP Model 2748A Paper Tape Reader, and an Antekna manufactured Device Interface Unit (DIU). Except for front panel control settings of ancillary devices,

magnetic tape inputs to ancillary devices, and patch panel connections of ancillary devices, the operation of the stimulator is under computer control during the period of a simulated mission.

Instructions for operation are entered into the CCC, where they are stored in buffer memory, via punched paper tape and/or the teletype unit. The instructions establish the initial time an RF emitter appears, its signature (i.e., those parameters such as, pulse width, pulse repetition frequency, beam width, scan type and rate, etc.), the emitter's initial range and bearing, and its course and speed and possible turning maneuvers at the outset or later in the exercise. The computer calculates new range and bearing information at one-second (or longer, if desired) intervals.

Once a scenario has been entered, the outputs of the CCC are either, a punched paper tape record of the inputted program, or a mission scenario run. A mission run is initiated by starting the real time clock. The basic time interval is one second but can be made longer; this, of course, will alter (speed up) the time scale of the scenario events. The computer outputs to the device interface unit are series of command words and data words. The command words identify the RF emitter devices to which the data words are assigned. The data words identify such RF emitter output parameters as carrier frequency, pulse width and pulse repetition frequency, and the elements of the antenna scan pattern. These data words are output at least once every five minutes, whether the parameters have changed or not, to guard against loss of information in the RF emitter devices. There are other data words as well which specify the emitter output level as a function of the simulated range, and specify the simulated bearing of the emitter. These range and bearing words are output once per basic time

interval. The computer uses the initial range, initial bearing, heading, speed, and rate of turn to calculate a new range and bearing when the clock advances a time interval, and uses the new range and new bearing to repeat the calculation on successive advances of the clock.

The computer outputs to the Device Interface Unit (DIU) (Antekna Model 5320) are binary outputs; but the data words to the RF emitter devices must be in BCD (binary-coded-decimal) format. The function then of the DIU is to convert the raw binary information to BCD, and output the newly-coded information onto a single data line which goes to the first RF emitter device in what is called a "daisy chain." An illustrative example of a daisy chain is shown in Figure 2. A BCD word arrives at the pulse generator which checks if there are any instructions pertinent to its function, then passes the word along the chain to the microwave source/modulator which checks, and then passes to the scan pattern generator, etc. Each RF emitter device contains line drivers which couple the data to the next device on the buss. Antekna claims the following benefits in this control transfer method: a) minimization of line reflections and system noise; b) decreased loading of the data source; and c) with minor exceptions, identical data coupling cables throughout the data system. Other characteristics noted by operators in the field include: a) inherently slower response because of the serial nature of the chain, but this may be more academic than anything else, especially when execution speed is not excessively critical; b) if one device in the chain fails, the subsequent devices are effectively inoperative (but conversely, this makes isolation of the faulty unit relatively easy and it could possibly be jumper by-passed during repair).

2. RF Emitters. The RF emitters are divided into two

major classes, "maneuverable" and "non-maneuverable." Those RF emitters whose outputs provide no simulation of variable range and bearing are termed non-maneuverable emitters. They are provided as 16 communications channels by an Antekna Model 7240 Communication Signal Source/Modulator. This unit has 16 RF sources at preset discrete frequencies from 5 kHz to 50 MHz, each source having independent AM and FM capability. Additionally, two channels provide LSB, DSB, USB or reinserted carrier signals. Front panel controls permit the operator to select the desired channel modes. The computer program exercises control only in turning these emitters on or off during the mission run. The modulating signal, if any, is selected by patch panel connection from one of the ancillary devices. The inputs to the non-maneuverable RF emitters are, therefore, ON/OFF commands from the CCC, and modulation signals from the ancillary devices. The outputs are modulated or CW RF carriers which are applied to the stimulator/receiver interfaces.

The maneuverable RF emitters provide simulation of range and bearing under control of the CCC. They are provided as 16 single-emitter platforms and 2 four-emitter platforms. A typical group of devices comprising an RF emitter includes:

* Programmable Pulse Generator (PPG), Antekna Model 1210
* Microwave Source Modulator (MSM), Antekna Model 3300
* Complex Scan Controller (CSC), Antekna Model 5310, an optional device which may not be used in all RF emitter groups
* Scan Pattern Generator (SPG), Antekna Model 1400
* DF Interface, Antekna Model 7232

All of these devices are programmable from a single daisy chain data bus, or all, except the DF interface, can be manually set from front panel controls.

The Programmable Pulse Generator supplies pulse

modulation signals for two targets. The output is a pulse train of specified pulse width (0.1 usec - 990.0 usec), and pulse repetition interval (0.2 usec - 9.99 msec), which is applied to the target microwave source modulator as a pulse modulation signal. For some targets, the connection from the PPG to MSM is made through a patch panel so that other sources may be used to pulse modulate the MSM. There is also a special version of the PPG which provides pseudorandom pulse jitter up to 999.9 usec with 0.1 usec resolution.

The Scan Pattern Generator generates antenna scan patterns. Its scan parameters include:

* scan rate (.001 Hz - 99.0 Hz)
* scan mode (conical, circular, unidirectional and bidirectional sector)
* main lobe beam width at the 3dB point (1° - 99°)
* sector width/scan offset angle (1° - 360°)
* sidelobes (first, second, and the remaining ones are digitally adjustable from 0 to 40dB below the main lobe).

The lobe shape or structure is internally (not computer controlled) adjustable to be ±30% of an ideal parabola. The conical scan track is adjustable from "search," to "lock on." As with the PPG, for some targets, the connection from the SPG to the MSM is made through a patch panel so that other sources may be used to amplitude modulate the MSM.

The Complex Scan Controller operates in conjunction with the SPG (target emitters 1 - 7 excluded) to produce more complex scan patterns than can be generated by the SPG alone. The input parameters to this device include:

* scan mode (Palmer, spiral, or raster)
* raster sector width (10°, 20°, 30°, 40°, 60°, or 90° horizontally, and 2° - 20° vertically)
* raster beam width (1°, 2°, or 4°)

So, in conjunction with the SPG the following scan patterns can be simulated:

* conical
* circular
* Palmer
* spiral
* raster
* vertical sector, both unidirectional and bidirectional
* horizontal sector, both unidirectional and bidirectional
* omnidirectional

The DF Interface used in conjunction with the 7B1/1 consists of 11 target outputs, all related to a single antenna system. The inputs to the Model 7232 are data words from the computer representing the simulated bearings of the different targets, and synchro signals from the antenna, defining antenna bearing. The output of each section is an analog signal, which has a shaped lobe centered at coincidence between target bearing and antenna bearing. The signal is applied to the Microwave Source/Modulator to simulate the DF effect.

The Microwave Source/Modulator supplies an RF carrier and modulates the carrier from externally applied signals. These applied signals include a computer output level word representing the simulated range of the target; a pulse modulation signal from the PPG; a level signal from the DF Interface; and an analog signal defining the antenna scan pattern, typically from the SPG. The MSM is capable of CW operation, pulse modulated output, amplitude modulated output, or combined pulse and amplitude modulation. Except when it is programmed to simulate an omnidirectional radiator, the MSM typically operates in this latter combined

mode. The output of the MSM is applied through RF combiners and splitters to the receiver inputs.

3. Ancillary Devices. These are manually controlled signal sources whose outputs, though not controlled by the CCC, are selectable through a patch panel for application to the emitter units to provide additional sources of modulation. In addition to the Model 7240 Communication Signal Source/Modulator which was described earlier, the following units comprise the Ancillary Devices: an Ampex Model AG 500-4 tape unit which provides 4 channels of audio signal; three HP 204C Sinewave Generators which provide sinusoids from 5 Hz to 1.2 MHz; and a General Radio Type 1390B Random Noise Generator which provides uniform wideband noise from 5 Hz to 5 MHz. Front panel controls provide adjustment of output level and low pass filter selection for ranges up to 20 kHz and 500 kHz. There is also an Antekna Model 1294 Pulse Code Generator and an Antekna Special Code Modulator, the latter of which provides the following types of signals: frequency shift keying (FSK); interrupted continuous wave; indentification friend or foe (IFF); intra-pulse AM; and telemetry signals such as PPM, PDM, FM/FM, and AM/AM.

4. Stimulator/Receiver Interfaces. These consist of DF interfaces (which have already been described) and RF combiners. The RF combiners basically combine the outputs of several platform emitters operating within a single band for application to receiver terminals.

Comments: The 7B1/1 represents a modest but still small scale implementation of an EW simulator. Although plans have been formulated to significantly improve its capabilities (some which are unclassified will be discussed momentarily), still it would be good to examine some of its current deficiencies.

Problems associated with the daisy chain data bus were discussed earlier; basically, if the module at the head of the chain fails, then the whole chain fails; i.e., there is no graceful system degradation, although the bad module may be bypassed once isolated. The number of target emitters available is very small and cannot provide for realistic signal densities. Of the 34 possible emitter platforms, the 16 which are exclusively communications emitters are non-maneuverable, cannot be DF'd, and have fixed frequencies - not a very realistic situation at all. Of the other 18 platforms, only 2 are multi-emitter (4), the remaining are single emitter - again not very realistic. And 7 of the 18 platforms cannot make use of the Complex Scan Controller, not necessarily a critical point, but a limitation nevertheless.

Modifications to signal parameters through instructor/operator control cannot be executed while the scenario is being run. Changes must be made after the program has been loaded but before execution has begun, or the program must be interrupted to insert a change for an instant future to the stop-time. This does not allow the instructor much flexibility in parameter modification.

In conversations with personnel associated with the Groton installation, the system is reported to have too low an output because of the line losses suffered in signal transmission, and post amplification appears to make the noise problem even more severe.

As for projected modifications/improvements, the following unclassified ones are of significance. The density of both COMINT and ELINT emitters will be increased. At the present time all parameters for a particular emitter must be repeatedly specified. The updated system will see introduced computer aided scenario preparation wherein

comprehensive emitter signatures and platform configurations will be held in a library for call-up when desired. Finally, new interfaces will be developed to accomodate two additional receiver systems.

B. NAVAL ELECTRONIC WARFARE TRAINING SYSTEM (NEWTS), DEVICE 10H1

This particular simulator is not yet in the Navy's inventory of EW training devices, yet its scope is so broad and its possible impact of such import, that it deserves to be discussed well before its inception. The trainer is a generic EW simulator incorporating elements of computer-assisted instruction (CAI), and computer-managed instruction (CMI). It is being designed/built by Grumman Aerospace Corporation, and will be installed at the Consolidated Naval Electronic Warfare School, Corry Station, Pensacola, Florida. As of this writing, Grumman has fixed the large scale hardware design, and is presently working on software and detailed system design. A User Project Team (UPT), comprised of military personnel at Corry has been formed to formulate the first instructional strategies. A prototype unit is expected at the end of 1977; various facets/stages of installation testing will be conducted throughout 1978; and the first full-fledged input of students will hopefully be processed in Spring 1979.

NEWTS is an inovative development in systems engineering; it is the first large scale merger of traditional simulation techniques (although there will be some signal generation, most of the displays will be synthetically driven) with CAI in one training environment. [5] It is designed to provide <u>basic</u> EW training for generic surface, subsurface, and airborne EW systems. It will not necessarily be using actual EW equipments used in the field,

or even their front panels. Rather, it will drive front panels which are <u>like</u> those on present equipments, to the extent they perform similar/exactly the same functions. It is intended that students trained on this system would proceed to follow-on training which would utilize actual field equipments. Because of its flexibility, NEWTS is expected to assist in the training of specialists of as diverse backgrounds as: ET's, AT's, CT's, EW's both rated and non-rated, NFO's, surface EWO's, Marine personnel, and staff personnel assigned to EW and training duties. When the system is completely outfitted, it is expected that some 2500 students per year could be processed through NEWTS. One should caution however that NEWTS in and of itself does not comprise the whole of the training concept, it is intended to be only a portion of an overall training program that would still include traditional classroom/group instruction, and other audio-visual techniques. What NEWTS would provide is not only the opportunity to practice certain intellectual/motor skills associated with EW watch standing (e.g. recognizing a signal type, then measuring its parameters) but, through its ability to simultaneously stimulate several "watch" stations, also begin to focus on the elements/importance of coordinated team effort well before a man gets out into the field where cooperation and coordination are of the essence. Specifically then, the trainer is employed as the training vehicle for EW exercises, generic systems familiarization, operator skills development, operating techniques, electronic warfare capabilities and limitations, and EW team-type training.

1. <u>Technical Features</u>

Both the system hardware and software are being designed on a modular basis so that future changes may be more readily incorporated. There are also two other advantages: it will allow for protracted piecewise purchase of system

components, rather than having to buy the whole system at the outset (although it is recognized that inflation will certainly result in a price increase on items purchased later); and it will allow for thorough testing of the first increment of components to verify system specifications before committing the remainder of the alotted funds. The trainer then, is modular in design and consists of: on the lowest level, the student trainee station (maximum 70 stations); at an intermediate level, a simulation subsystem to control as many as 20 student stations; and, at the highest level, an executive subsystem to perform control and mass storage of emitter library, standard exercises, and student data.

In addition to that mentioned above, the executive subsystem provides all fetch, distribution, and availability functions relative to the trainer utilization. It includes a supervisor console for off-line programming, mission preparation, syllabus generation, system control, and monitoring of current student station system status/usage. A digital computer system with peripherals handles all operational and administrative functions. The executive software primarily is concerned with trainer management. It maintains the data bases used by each of the subordinate subsystems, and accepts alterations to the training exercises.

The simulation subsystem is the controlling system for 20 student stations. It provides the following control functions for the student stations (either taken individually or in groups):

a. establishing EW equipment configurations

b. assigning specific problems and scenarios, including CAI

c. establishing the physical environment (including number, type, and location of emitters)

d. inserting and removing malfunctions

e. scoring and keeping records for each student

f. operating the student station to start, freeze, reset, etc.

g. coordinating activities for up to five student stations acting as a team on one platform

h. coordinating activities of two or more platforms in a common electromagnetic environment

i. establishing internal and radio communications networks

j. providing simulated video and voice recordings, and hard copies of the student station instructional display pages.

The simulation subsystem consists of two major units: the simulation computer; and the instructor/device operator console. Peripheral equipment provided with the simulation subsystem includes a teletype unit and large capacity bulk storage. In addition, it contains a PPI video simulator which generates video for all targets in a specific exercise. The simulation subsystem software controls and monitors the training exercises. It maintains the electromagnetic environment, provides CAI, and scores and/or evaluates individual student performance.

The student stations, of which there will be a maximum of 70 in NEWTS, each consists of:

a. a general purpose digital computer

b. a signal generation unit, capable of simultaneously providing two discrete baseband signals for detailed analysis; this unit also provides the capability to drive multiple activity displays corresponding to the electromagnetic environment and receiver characteristics

c. a receiver/display interface unit, consisting of two programmable receiver models, each capable of processing one of the two detailed video outputs of the signal generation unit

d. a data gating and encoding unit, basically a buffer to the computer buss

e. a data storage unit, which steers computer output data to memory elements in order to illuminate the panel indicators that establish the operational characteristics of the exercise

f. receiver display and control panels consisting of computer-controlled hardware devices to simulate a generic variety of EW equipments

g. two graphic/alphanumeric CRT's, an alphanumeric keyboard, and five CRT's to simulate five-trace analysis displays, polar DF displays, IFM spectral displays, panoramic displays, etc.

The student station software interfaces with the system hardware to generate signal environments, it monitors

student reaction, and drives the generic panels to represent specific equipments.

In addition to the software associated with each subsystem noted above, there are four other software categories which will be briefly outlined:

a. Training Exercise Operational Programs, which manage the operational aspects of the training exercise for all computational levels

b. Training Support Programs, which cover all software programs that directly support the automation of syllabus generation by the instructor, course authoring, and delivery to the student

c. Software System Support Programs, which are designed to simplify program development and implementation

d. Maintenance Test Programs, which help isolate failures in the system.

For all modes of operation, the simulation system represents a tactical electromagnetic environment in a geographic gaming area, 512 by 512 nautical miles, from sea level to 100,000 feet. Fourteen signal masking curtains permit the simulation of terrain blocking features which affect signal detection and intercept by sensors located within the detection envelope. A curtain can be up to 512 nautical miles long in one surface coordinate and from sea level to 20,000 feet in height.

The environment consists of 256 different pre-programmed emitters among which are the following and their special features:

a. up to 128 emitter types available for use in a problem, with up to 32 independent emitters that may be detected at any given time at a student station

b. up to 32 simulated platforms (friendly and/or hostile, one of which is own ship) to which emitters may be assigned and tracked

c. some 32 emitters with the maximum received signal strength (on a line-of-sight relative to own ship) available for display at any given student station

d. emitter signals represent radars, data links, communications, electro-optics, and navigation-type transmissions; they affect displays, aural tones, controls and indicators on the simulated equipments of the student station and instructor/device operator positions

e. Emitter signals, on fixed or on moving platforms, are capable of being positioned or repositioned anywhere in the gaming area at any time during the exercise. The platforms are capable of being designated as trackable, moving vehicles or stationary, position selectable bases, and represent "origin of emission" for any combination of one to 32 assignable emitters. Platform motion is simulated by equations within the student trainee station computer with velocity ranging from 0 to 4096 knots in X, Y, and Z coordinates, and with turn rates from 0 to 6 degrees per second.

2. Features of CAI/CMI

Why should the Navy invest in such a sophisticated computer-controlled EW training system? In the face of very real limitations in the number of instructor billets available, and yet with the requirement to provide quality

training which can best come from individualized instructor attention, a compromise is obviously necessary. The compromise reached was to create an _effective_ 1:1 student/instructor ratio (actual will be 10:1) through the assistance of a computer. The computer, programmed with exercises, questions, and instructional strategies, teaches and directs each student through his course of instruction. The instructor, on the other hand, now time-shared among 10 students, operates in a management-by-exception mode; he attends to or intervenes in a student-computer loop only when he detects, or is alerted to performance that deviates from the instructor-established criteria.

First, what is the difference between CAI and CMI? It is at best a very fine distinction since the two are closely intertwined. The emphasis in computer managed instruction (CMI) is on the administration of tests and maintenance of scores and records. On the other hand, computer assisted instruction (CAI) is more closely akin to the actual provision of instruction. The computer is effectively replacing the instructor, and, depending on the knowledge level of the student, provides particular learning sequences (including new materials and new test questions) deemed most appropriate. The fact that both of these are often provided within the same computer system attests to the close link that can exist between them.

Noted advantages of CAI/CMI, most of which are applicable to NEWTS, include: individualized instruction; reduced training time; improved management of training; standardized training; quick updating of courses from a central location; and better training evaluation. The individualized instruction characteristic is particularly appealing in NEWTS because each student can: work at his own pace; begin and end the training exercise whenever convenient; begin at a point appropriate to his past

achievement; receive instruction tailored to a particular application; stipulate his preferred mode of presentation (i.e., graphics, verbal, aural, etc.); select his preferred type of reinforcement; have his deficient skills or knowledge diagnosed and remedied; react to the immediate past history of responses; and follow his own most effective presentation strategy.

PLANIT (Programming LANguage for Interactive Teaching) is the computer programming language for CAI in NEWTS. In its basic form (it has been used extensively in other CAI applications), it allows any user to interact with an instructional program as a student; it also provides instructors with a programming language for authoring instructional programs. In addition to this, in NEWTS, PLANIT will include interfacing programs which will communicate with the equipment and simulation programs to control the student station panels so that they represent the specified equipments with which the student is called to work.

Comments: It is difficult to find glaring faults with the NEWTS concept. It will provide good basic EW training to a diverse group of specialists. It will be (or at least attempt to be) all things to all people. And herein may lie one of the problems: cost. This writer has not been privvy to any cost estimates on this project, and is not equipped to make any. But it is pretty much acknowledged that when there is a great amount of software involved, there is also exceedingly great cost involved. Since PLANIT is an already established computer language, the cost impact might hopefully be lessened.

The modular nature of the system, that is, the executive, simulation, and student station subsystems, is an attractive feature, particularly the capability of an

individual student station to function independently because it has its own dedicated computer. This allows for self-paced study, and from an engineering point of view, the failure of an individual station should not affect others in its simulation subsystem. It is quite obvious however, that if instructor/device operator consoles fail, the associated student stations would be lost unless alternate means are provided to at least load them for individual instruction even if without the capability for remote instructor intervention. An executive subsystem failure would probably secure the entire system.

There is also, I believe, one serious matter that should be discussed in the context of this individualized instruction that results from CAI/CMI, and that is the loss, or at least significant reduction, of the personal touch inherent in a teacher-student relationship. Admittedly there will be an instructor overseeing some 10 student stations, and it is well understood that one of the prime reasons for implementing NEWTS is to make more efficient use of fewer instructors in order to reduce training costs. It has not been shown (and I do not know that can be), that ten students simultaneously under instruction can be effectively monitored by one instructor; he just might be overburdened. He might not have the time to provide encouragement, or refine operator techniques, both of which are best undertaken on a personal one-to-one basis. The "self-paced" feature of individualized instruction is also fraught with the danger of malingering or laziness. For those students who are slower to learn, the feature is of unquestionable worth and benefit, but instructors will have to remain vigilant. Applying a bit of pressure on students to perfrom is not necessarily a bad thing. The EW environment can be a very pressure-laden one, and the sooner trainees become aware of this, the better equipped they will be to cope with it.

C. 10A3/1,2,3 STIMULATORS

The 10A3 series of stimulators presently consists of three EW simulation systems manufactured by Antekna, Inc., which are installed at the Navy Technical Training Center, Corry Station, Pensacola, Florida. Although the systems use many of the same modular components and simulation techniques enumerated in the 7B1/1 System, all three are of improved design, and the 10A3/2 has a significant electronic countermeasures (ECM) capability as well as an electronic support measures (ESM) one. The 10A3/1 is a general purpose ESM trainer, while the 10A3/3 is particularly dedicated to training the CTT ratings in ELINT ESM techniques. The following presentation will focus on the 10A3/1 system. It will then be followed by brief summaries outlining the differences of the 10A3/2,3 with respect to the 10A3/1. For specific information concerning some of the modular components, the reader will be referenced to applicable descriptions under the 7B1/1 section.

The 10A3/1 system simulates an electromagnetic environment whose signals are fed into operational ESM equipments.[6] It has the capability of generating 10 emitter targets in the 7 - 11 GHz range broken down into AN/WLR-1C frequency bands as follows: 2 targets in Band 5; 2 in Band 7; 2 in Band 8; and 4 in Band 9. All of the targets are maneuverable and can be DF'd. Twenty AN/WLR-1C receiver systems can be simultaneously driven by the 10A3/1.

The system consists of two major subsystems: the computation system; and the RF emitters. The computation system typically consists of: an HP 2100A Computer; an HP 2600A CRT Terminal; an HP 2748 Punched Tape Reader; an HP 2895 Tape Punch; an Antekna Model 5320 Device Interface Unit

(to provide an interface between the computer and emitter elements); an Antekna Mission Time Monitor; and a Dicom 344 Magnetic Tape Unit. In general, the computer and its peripherals, through its software, allows the programming of scenarios. During program execution it controls emitter parameters, and the aspects of problem geometry. More specifically an instructor can, via his keyboard:

1. Start, stop, and resume the running of a scenario.

2. Input scenario parameters from the keyboard, paper tape or magnetic tape cassette.

3. Create scenarios on paper tape or a magnetic tape cassette. This can be done concurrently while a mission is in progress.

4. Take control of the course and emitter signature of moving ships (both own ship and targets) while a mission is in progress.

5. Change the basic interval time to either increase or decrease the pace of the exercise.

It might be worth a moment to examine some basic differences/improvements in these control features as compared to the 7B1/1. The addition of magnetic cassettes should make both the handling and storage of mission scenarios more convenient; the 7B1/1 was uniquely paper tape storage. The ability to take control of a platform while the mission is in progress is certainly an added plus; the 7B1/1 required total interruption of the run to insert changes. It should be noted however, that once manual control of a target has been assumed, the instructor cannot revert to the pre-programmed mode without restarting the program at time 0000. This would almost seem to be a

logical restriction insofar as control of platform course headings, etc., but an instructor might want to periodically alter an emitter signature for only a short portion of an exercise, and with the system as it stands, he would have to stay by the keyboard for the whole of the exercise--a possible inconvenience. In the 7B1/1, time intervals could only be lengthened to speed up the mission run; with the 10A3/1 they can be shortened so as to slow the run down to below its nominal one-second time interval. This ability to slow the mission down could be helpful for instructional purposes.

The RF emitters are basically identical to those of the 7B1/1. Each "emitter" consists of: a Model 3300 Microwave Source/Modulator; a Model 1210 Pulse Generator; a Model 7232-04 DF Interface Unit; a Model 1400 Scan Pattern Generator; and, if required, the Model 5310 Complex Scan Controller. (Refer to the 7B1/1 section for specifications.) With the scan pattern and complex scan units, the following scan types can be generated:

* omnidirectional
* conical
* circular
* unidirectional and bidirectional sector
* Palmer-circular
* unidirectional and bidirectional raster
* spiral conical.

Motion of own ship and the target emitters is programmable. Motion parameters for own ship include, heading, speed, and rate of turn. For target platform, additional parameters include bearing and range to target with respect to own ship, and a parameter called the "gaming range" (in nautical miles). When a target platform is at its gaming range with respect to own ship, its signal is at 60dB attenuation with respect to own ship's receivers.

The 10A3/2 System was designed to incorporate elements of ECM training while maintaining those of ESM already existent in the trainer.[7] Some of the basic features of the system include: a two "own ship" capability with the units usually operating concurrently to simulate a coordinated task group operation, although they are capable of separate and independent exercises; ECM interaction between student and computer with a resultant change in the simulation scenario when proper countermeasures are taken; a 15 target emitter capability in the .5 - 18 GHz range; video inputs to AN/SPA-25 radar repeaters for correlation with other electromagnetic signals (for target emitters within 300 nautical miles); and the capability to simultaneously drive four AN/WLR-1C receiver systems (Bands 5,7,8,9), two AN/ULQ-6B countermeasures sets remote control units, two AN/SLR-12A countermeasures receiving sets, and two AN/SPA-25 radar repeaters. The basic differences between this system and the 10A3/1 lie in the RF emitters, and, of course, in the added ECM cpapbility.

First, the target emitters are divided into three groups: 1) general targets (nos. 1 - 9); 2) ECM targets (nos. 10 - 13); and 3) SLR-12A targets (nos. 14 and 15, video). The ECM targets can perform as general targets, but additionally their signature characteristics can be modified by the action of the simulated ULQ-6B countermeasures set. There is also the matter of frequency assignment. Emitters 1 - 13 generate RF threats, and emitters 14 and 15 provide both RF and video for simulation of K-band targets, but simultaneous threat frequency assignment during a scenario is constrained by the Model 3300 Source to the following:

* nos. 1,2	0.5 - 1 GHz
* nos. 3 - 5	2 - 4 GHz
* nos. 6,7	4 - 8 GHz
* nos. 8 - 13	7 - 11 GHz
* nos. 14,15	12.4 - 18 GHz + video simulation

Motion of emitters is like with the 10A3/1 except that bearing and range must be specified from one "own ship" to the other and bearing and range for the target emitters must be specified with respect to one or the other "own ship."

The ECM functions associated with targets 10 - 13 come into play when one or all of these is in a conical scan mode. Other parameters associated with ECM action include specification of "burn-through range" (minimum distance from enemy emitter at which your ECM will "protect" you) ; if the range between own ship and target emitter is less than the burn-through range, any ECM action will be judged ineffective and no reaction in the form of simulation alteration will take place. Similarly there is an "enhanced acquisition range" parameter beyond whose range ECM actions would be judged ineffective, an so no reaction would take place.

There is little to say about the 10A3/3. It is very much like the 10A3/1 System except that it consists of a maximum eight maneuverable targets in the 0.5 - 11 GHz range and drives only four AN/WLR-1C receiver systems.

D. THE ELINT AND COMINT RECEIVER TEST SYSTEM (ERTS/CRTS)

This last of the EW simulators that will be reviewed is being designed and built by the Martin Marietta Corporation - Denver Division for the Naval Electronic Systems Engineering Center (NESEC) located in San Diego. Briefly summarized, the two systems will simulate an electromagnetic environment of radar and communications signals primarily intended for receiver evaluation, and possibly at some future date, for personnel training as well.

1. Elint Receiver Test System

ERTS is designed to simulate an electromagnetic environment in the 2.0 - 4.0 GHz, 8.5 - 10.0 GHz, and 13.0 - 15.0 GHz frequency ranges.[8] The system consists of two hardware subsystems, one digital, the other RF/analog, and a supporting software subsystem.

The RF subsystem has six independent and modular channels with a capability to expand to eight (the support circuitry needed for the two additional channels is incorporated into the basic design). Channels 1 and 2 operate from 2.0 - 4.0 GHz, 3 and 4 from 8.0 - 10.0 GHz, 5 and 6 from 13.0 - 15.0 GHz. One RF channel consists primarily of a frequency agile voltage controlled oscillator (VCO), a switched attenuator, an amplitude modulator, and a band pass filter. (See Figure 3)

Voltage-controlled oscillators have the advantageous capability to be rapidly tuned across their complete frequency range; however, they are difficult to set on a precise frequency and are hampered by post tuning drift. To counter these characteristics, Martin Marietta has devised an automatic frequency calibration scheme to keep the VCO on the desired frequency.

The Switched Attenuator (SWAT) consists of two high speed diode switches and two attenuators. It is used to generate two different rise and fall time states (fast mode: rise time - 30 nsec, fall time - 40 nsec; slow mode: rise time - 60 nsec, fall time - 80 nsec), and to select four different amplitude states (minimum insertion loss, 30 dB attenuation, 60 dB attenuation, and a 100 dB isolation state). Pulse width is also controlled by this switch.

The Amplitude Modulator provides the necessary modulation due to transmitter antenna gain and range attenuation, and it works in conjunction with the four SWAT amplitude states. The modulator has a total dynamic range of 40 dB (only 30 dB of which is used due to the 30 and 60 dB attenuators in the SWAT). Whenever the modulator reaches 30 dB attenuation, it returns to its minimum insertion loss state and the SWAT is incremented 30 dB. Total dynamic range is approximately 100 dB.

The Band Pass Filter provides harmonic rejection and video leakage rejection. Outputs from the two respective channels in any one band are then sent on to a frequency diplexer. The second input at the #1 output port diplexer is a 950 - 1200 MHz signal provided by an RF Scenario Generator (GFE). The two inputs to the #2 output port diplexer are the power combined RF channels, 3/4, and 5/6. External directional couplers are provided for each output port, providing the capability to couple in external signals. The RF Scenario Generator is a telemetry signal generator mounted in the CRTS equipment racks and controlled by CRTS software. It has two output ports, one from 950 - 1200 MHz connected to ERTS as described above, and a second one in the 50 - 300 MHz range to CRTS. Signals at a specified frequency are routed to the appropriate output port as commanded by the CRTS program.

The Digital Controller Subsystem interfaces with a tape transport that contains software generated data describing the RF environment. The digital subsystem performs three major functions: the generation of pulse trains; storage and updating of current emitter descriptions; and assignment of pulse executions to specific RF channels. It has the capability to simultaneously control a total of 64 emitters (32 active/foreground emitters, and

32 background emitters) through a time division multiplex scheme explained below.

To initialize an emitter, it must be given a PRF descriptor, a full data description in its memory location (frequency, amplitude, pulse width, etc.), and a turn-on code which activates its PRF generator. Once the PRF generator is activated, it will periodically issue signals indicating that an RF execution is required. A scanning processor is continually monitoring all 64 emitters for an active condition. When such a condition is sensed, control is passed to the scheduling processor, which determines what frequency band is required, and whether or not a channel is available. Control is then passed to a channel control board, and the scanning and scheduling processors are released to locate another active emitter. Once an emitter has been initialized, it continuously receives updates at a rate determined by the software, which effectively describes the dynamic changes for that emitter.

Some of the hardware comprising the digital subsystem includes three media for data input namely, magnetic tape, a card reader, and a manual keyboard via the microprocessor. The microprocessor is programmed such that amplitude is specified in dB, frequency in MHz, and PRI in microseconds. This allows the operator to program static emitters or to manually update pre-programmed emitters.

The storage section of the digital subsystem includes the memory and memory control circuits. The system configuration is such that the memory contains the current emission descriptors necessary to produce up to 64 independent emissions. These descriptors are available to be updated with an input operation, or to produce RF emissions outputted to the RF system. PRF information and

band data is stored in discrete storage registers under software control.

The pulse train generation circuits generate up to 64 emitter pulse trains of the following types: 55 emitters produce simple periodic timing (PRF's of 50 Hz to 20 kHz); 3 emitters produce random, sinusoidal, and triangular PRI (frequency of the modulation is controllable from 0.01 to 30 Hz); and 6 emitters produce four-position stagger PRI. Of this 64-emitter total, 32 of the simple periodic timing variety are to be used as background emitters.

The ERTS software will operate on an IBM 370 computer. It consists of three major subsystmes: the File Generation Subsystem; the Simulation Subsystem; and the Output Subsystem. (See Figure 4)

The File Generation Subsystem is independent of the actual simulation run and will only be in core while inputting mission scenario data. This subsystem stores all the data required to run a given mission simulation in disk files. The information remains on the disk until revised, or changed by the user. (The other two subsystems are loaded whenever it is desired to run the simulation described by the current disk files.) The information required to describe a mission scenario is composed of the following data files:

1. Antenna Patterns. This file may contain up to 18 records, each representing an antenna pattern cut. During a simulation, any two of these cuts can represent the azimuth and elevation cuts of an emitter or receiver antenna pattern. Fourteen records will initially be provided by the manufacturer, the remaining four alotted for future expansion. The patterns are characterized by their 3 dB

beamwidth and 5 of the 14 are cosecant-squared antenna patterns.

2. Emitter Description. This file may contain up to 255 records describing 255 possible emitters deployed in a given arena. This does not mean you can have 255 emitters simultaneously deployed (this is still limited to the 32 foreground and 32 background emitters). This is just a library of possible/available emitter signatures. Signature specifications include the following:

* Frequency
  - 2.0 - 4.0 GHz
  - 8.0 - 10.0 GHz
  - 13.0 - 15.0 GHz
* Polarization
  - circular
  - linear
  - rotating dipole
* Operating Modes
  - CW (one max per RF channel)
  - stagger PRI
  - sine wave PRI
  - triangular/ramp PRI
  - frequency hop
  - frequency slide
  - special functions generation
* Location: two time-flagged inputs describing start and stop locations (latitude, longitude, and altitude)
* Scan Types
  - circular
  - sector
  - unidirectional sector
  - circular nodding
  - fixed azimuth nodding
  - sequential lobing/lobe switching
  - conical

- spiral
- Palmer circular
- Palmer sector (unidirectional and bidirectional)
- azimuth raster (unidirectional and bidirectional)
- elevation raster (unidirectional and bidirectional)
- azimuth raster Palmer (unidirectional and bidirectional)

* Peak Power
* Antenna Pattern Numbers
* Pulse Width: 0.1 - 200.0 usec in 100 nsec increments.

3. "Flight" Path. (The name originated with Martin Marietta simulation systems designed particularly for aircraft, and has been retained by the manufacturer. The "flight" path describes the movement of the receiver platform be it in the water, on land, or in the air.) This file will consist of a possible 3600 records representing 3600 possible changes in the receiver platform position, or attitude. The information includes time, location (in latitude and longitude), roll angle and roll rate (particularly applicable to aircraft), or changes in the antenna pointing directions. The programmer specifies the position of the receiving platform in terms of latitude and longitude on the gaming area at given integer minutes of time. The computer then moves the platform at a constant velocity along the straight line path between two successive positions. Changes in emitter signal strength are appropriately reflected at the receiver inputs.

4. Emitter Encounter. This file will contain a maximum of 100 records which describe the changes in the active emitter status (excluding position) each second. The 32 foreground emitters are software controlled on a

pulse-to-pulse basis. Power variations due to antenna scans of background emitters will be controlled by the hardware system. As far as movement of the emitters is concerned, only the 32 foreground emitters can move. They can make but one movement specified by a start time and position and a stop time and position. Motion is along the straight line between start and stop points at a constant velocity computed from the start and stop positions/times. Any changes in signal strength are reflected at the receiver input ports. If the emitter is so distant that the calculated signal strength falls below a preset threshold (default; -150dBm), the signal will not be generated at RF, but neither will its existence be eliminated from memory, should future unit dispositions result in increased/detectable signal strength.

5. Antenna Deployment. This file contains the number, location, pointing direction, and pattern identification of a maximum four possible receiver antennas.

6. Calibration Data. This data is required to translate mathematical simulation results to hardware commands. This procedure is required due to the non-linearity of the simulation hardware.

The Simulation Subsystem's primary functions are: to initialize to a specified start time (it need not be time = 0000); to initiate the run; trace the path of the receiver platform; and make the necessary calculations relating to platform position/attitude and pulse-to-pulse updates for all emitter contacts. Using the data files built by the File Generation Subsystem, the Simulation Subsystem will step through a scenario in time increments as small as 500 usec. At each step, data is calculated in support of the RF environment being simulated which is translated into time ordered signal power levels at the

receiver ports. The maximum length for an uninterrupted simulation run is 18 minutes. This could be extended with a second tape drive unit keyed to start when the first one terminated; without the second tape drive, manual reloading is required.

The Output Subsystem either produces a mission tape in format required by the simulator, or, it can provide a second-by-second printed account of the simulated environment.

Finally, a brief word on the mathematical simulation model. First, the earth is considered to be flat and is divided into equal degrees of latitude and longitude, that is, a fixed value of nautical miles per degree of latitude/longitude is used. The movement of the receiver platform is defined in straight line segments. Free space signal transmission is assumed, and in the scenario area, all emitters are considered to be in receiving range, so long as the signal has a sufficient signal strength.

2. COMINT Receiver Test System

CRTS is a general purpose communications signal environment simulator, operating from 10 kHz to 400 MHz in specified bands numbered 1 through 11 (See Figure 5), and designed to compliment the functions/capabilities of the ERTS.[9] As with ERTS, it can be considered as three separate subsystems: software, digital and RF. (See Figure 6) But before proceeding on to a description of these three subsystems, it might be appropriate to discuss a rather unique characteristic of the system, that of voice and Morse code script usage. There is a variety of modulation sources utilized in CRTS, but the three basic ones are voice, Morse code, and teletype. The last of these, the teletype, is generated in the digital subsystem, but the voice and Morse

each make use of up to 1000 prerecorded scripts. The voice scripts are first written out and numbered, then read into a microphone (or transcribed from tape), converted to a digital format, recorded on magnetic tape, and later transferred to a disk file for random access. This file will then serve as an input data file to the software subsystem when generating a mission tape. Similarly, a script may be written for a variety of Morse code transmissions. The message text is keypunched onto computer cards, is converted to a binary format and ultimately gets placed on a disk file as did the voice scripts.

In its initial configuration, the RF subsystem will consist of 64 active foreground emitters and a maximum of 610 background emitters. The system has designed into it the provision to expand the number of active emitters to 128 at some later date. Frequency bands, maximum number of simultaneously active emitters and the available modulation types, which will be explained later, are given in Figure 5.

The emitter module contains a highly accurate and stable CW source that is phase-locked to the system reference clock. A combination of circuitry in the "modulation sources" and the "emitter module" results in the modulation types listed in Figure 5. The FSK (frequency shift keying) modulation is used to simulate teletype signals of five and seven-bit code groups. The frequency shift deviation is programmable from 250 to 1000 Hz (50 to 150 Hz in Band 1), and the baud length can be 0.5 to 34 msec in length. The bandwidth of the modulating signals in AM DSB, AM SSB, and FM is the "typical" 300 - 3000 Hz usually associated with voice. Both manual and automatic Morse can be simulated. The word rate is programmable from 8 to 35 words per minute (one word = 5 characters, one character = 2 dashes + 2 dots, one dash = 3 dots). For manual mode Morse, a random one to ten word per minute variation in word rate

is provided. In FM, the maximum frequency deviation is ±10 kHz in Band 8 and ±30 kHz in Band 10. The pseudorandom pulse width modulation is provided by an internally programmable PRF generator in the Band 9 emitter module over the frequency range of 20 kHz to 30 kHz.

The overall operation of the emitter modules is as follows: An initialization block is routed from the mission tape to the data receiver in the appropriate emitter module. This data includes the time into the mission that the emitter is to turn on, time to turn off, frequency, amplitude, type of modulation, and a code to select the desired modulation source. At the prescribed second in the simulation, the emitter module will turn on with the proper modulation and amplitude. At the prescribed shut-off time, the emitter will turn off and may then be reinitialized with parameter data to simulate a different emitter. The outputs of all 64 (later 128) emitter modules are combined and multiplexed into a single RF output port along with the background signals and the RF Scenario Generator (50 - 300 MHz).

The digital subsystem contains a digital tape deck which reads the mission tape which was generated by the software subsystem, during an actual simulation run. Mission data is transfered to the digital controller which initializes, and later updates as necessary, the modulation sources. The resulting modulation data is time division multiplexed onto a data bus supplying the emitter modules.

The data sources which have inputs to the digital controller are the same as with ERTS, namely a tape transport, a card reader, and manual keyboard via a microprocessor unit.

There are 32 modulation sources in all, all time division multiplexed to the emitter modules. Four of these are voice, 12 are FSK/TTY, 12 others are Morse code, and four are audio bandwidth (300 Hz - 3000 Hz) external input channels to emitter modules in the 2 - 400 MHz range, for any GFE sources. The RF Scenario Generator (GFE) is also under the immediate control of the digital subsystem.

The software subsystem needed to support CRTS is executed off-line much as with ERTS. It translates user input test/environment data into time ordered, formatted hardware commands stored on tape. The duration of a simulation run is quite different from the ERTS. Whereas ERTS has an 18 minute maximum which incidentally is the approximate time for a tape to be fed continuously through the tape drive at 45 inches per second, CRTS simulation run duration, because of the way instructions are extracted from the data blocks, could last in excess of one hour and possibly two; it depends on the complexity of the simulated environment and the number of changes-- the less complex the environment, the longer the run can last. One element that probably contributes to this is the virtual lack of motion by the receiving platform and of very few target emitters. What motion there is in the receiving platform is limited, and most emitters are considered fixed in position.

The source descriptions under control of the software system include the voice, Morse, and TTY modulations mentioned earlier, but not the external inputs provided from other sources. The software system will support the control of 128 signals from a file of 450 signal descriptions. (This concept is similar to the 64 emitters which come from the 255 signal descriptions in ERTS.) The following signal description input data is needed to generate the required emitter module data block:

* Frequency: 10 kHz to 400 MHz
* Amplitude: -10 to -90 dBm
* Modulation Source Number: 1 - 32
* Timing: ON/OFF time in seconds
* Modulation Type: AM, FM, FSK, etc. limited to that available in the corresponding frequency band.

The software system will also support 610 background signals from a file of 100 emitter descriptions. Characteristics of the background emitters will be identical to the emitters of interest except their dynamic range is limited to 40 dB (-50 to -90 dBm). Those background emitters all characterized by the same unique modulation are software controlled as a group. For example, within a group all the background emitters have about the same amplitude (±2 dB), and each group is independently controlled in amplitude. In addition then to the input data needed to generate primary signals of interest, signal density and spacing need to be specified. There are four background generators for each of the two ranges in which they exist; i.e., there are 4 generators for the 2 - 10 MHz range and 4 others for the 100 - 150 MHz range. Each generator puts one type of modulation on all its output signals, e.g., all AM, or all FSK, or all Morse code. Signal density is 5 - 17.5 signals/MHz in the 2 - 10 MHz band (for a possible maximum number of signals of (17.5 sig/MHz) X (8 MHz) = 140 signals); and .05 - .25 signals/MHz (for a possible maximum of (.25sig/MHz) X (50 MHz) = 12.5). The maximum grand total of background emitters is then (4 generators X 140 sig/gen) + (4 generators X 12.5sig/gen) = 610 background signals. The signals can be interleaved/spaced so as to minimize overlap.

The script input comes from the previously described library of prerecorded voice and Morse code transmissions of varying length (1 - 10 sec) and content. The input data

needed for software control includes, the source identificaiion, script number and the transmission start time.

Comments. ERTS/CRTS ought to be judged in the light of the primary purpose for which it was conceived, namely test and evaluation of receiving systems. Although the emphasis in this paper has been to examine EW simulation vis-a-vis passive intercept training, ERTS/CRTS will provide the important capability of component and system's test discussed in the earlier sections of this paper, and so should not be discounted.

The basic idea behind ERTS/CRTS is to generate many different signals at various signal strengths and in varying densities to see if the system under test can properly process them and/or to see what the system's saturation point might be (this is particularly the case when testing automatic processing systems). In view of this mission, ERTS/CRTS will probably fulfill necessary requirements. The numbers of signals generated is substantial and the types of modulations quite varied. The 18-minute scenario length might be considered short but with the signal densities provided, if the system under test has not saturated in 18 minutes, it is doubtful that it would over a more extended period of time.

Nevertheless, it is possible that the ERTS/CRTS might be used as a trainer in the future. If this is so, the following current system characteristics would have to be reexamined.

The 18-minute scenario is too short for any kind of exercise and so the additional tape drive would have to be incorporated. The signal propagation models might need some modification. The assumption of free space signal

transmission does not take into account atmospheric considerations so that signal strengths might appear too strong for a given range between target emitter and receiving platform. The same sort of problem exists when the earth is assumed to be flat: line-of-sight limitations are not taken into consideration and so signal strength of normally line-of-sight-limited signals are ignored. This is not a very realistic situation.

The method for programming platform and emitter motion would have to be radically modified. It is just not natural to specify start and stop points/times as the only variables of motion and then have the unit proceed along a straight line between those points at constant velocity. Unit motion is always considered in terms of course, speed, rates of turn and so the system should be programmable in those terms. And while on the topic of unit movement, the CRTS capability in this area (currently almost nonexistent) would have to be severely upgraded and the COMINT and ELINT from a unique platform would have to be appropriately correlated in time and position.

Finally, the voice and possibly the Morse code script system might require some modification. The use of varied and short scripts to modulate carriers in a particular fashion so as to see if the system can correctly demodulate the signal is one thing, but to provide continuous and flowing transmissions is a very different situation. If rather than having a sequence of short interrupted scripts, a running tape of conversation could be accessed, this scheme might prove to be quite realistic and successful.

VI. FEATURES TO LOOK FOR IN A SIMULATOR

Choosing a simulator which is going to cost hundreds of thousands of dollars or more is no simple task. All manufacturers will tell you that their approach or solution to your simulation problem is the best. In the first seven subsections, desirable features for a simulator, particularly one designed for EW training, will be pointed out. The last subsection will focus on the type of simulator one might want for a particular simulation application/situation.

A. GENERATION OF A REALISTIC ENVIRONMENT

An electromagnetic environment simulator should be able to accurately replicate signal characteristics. This should include such things as: pulse width characteristics; pulse repetition frequencies including staggers, jitters, and codes; modulations like frequency agility and chirp; and antenna scan patterns. Real operational system sequences may require changes in PRF and pulse width, hand-off to associated radars, initiation of guidance sequences or initiation of ECCM modes, and so a simulator should be able to do likewise. Additionally, operational doctrine may include the colocation of acquisition and tracking radars, hand-off from early warning to point defense weapons systems, correlation of data from distant radars, and sequences of weapons system activation; the simulator should be able to accomodate these characteristics. The idea of a "gaming area," a limited region of encounter in three dimensional space may be a desirous feature. An area where realistic obstructions (e.g. mountains) can be introduced,

or where line-of-sight limitations are taken into consideration, is important so that characteristics of signal strength and polarization variations, at least from a geographical point of view, can be realistically simulated. Target movement within the playing area should be reflected in changes of signal strength and bearing. And implied here is the desirability of generating "DF'able" signals and providing the system with a DF capability. A realistically dense signal environment is also desirous not only because that's the way it really is, but also to see if an operator can correctly discriminate between important and unimportant signals, as well as to see if he can reasonably establish priorities for the important ones. These features are all desirable because one should want his operators to train under the most realistic conditions possible, and that includes a realistic enemy target in a realistic target environment.

B. THE ADVANTAGES/DESIRABILITY OF A MODULAR SYSTEM

One should look for a simulator that can keep pace with a changing EW environment. It is predicted that operating frequency ranges will grow and that signal densities will increase. In weapons systems there will be a continuing trend toward multiband signals, often with specific operational sequencing information contained in different signals and/or in different bands. A system should be designed with a flexibility such that, it will not only be able to generate current threats, but also be expandable in frequency range, signal density, signal modulation, and signal correlation. A modular design which is conducive to a building block approach is therefore desirous because it allows one to match today's EW environment, or at least buy as much of it as is affordable, and expand the system

size/capability along with new developments in the EW arena, or with increased availability of funds.

Some of the more specific large scale components one is apt to find in modular form might include: frequency generation elements to allow for expansion in frequency range; modular pulse and scan generators to permit intra/interband signal correlation, and increased complexity of signal parameters; direction finding interfaces to provide this characteristic inherent to mobile platforms; a modular computer capability to control the aforementioned components and allow for increased size and complexity in the future. One other feature that should not be overlooked in this type of system architecture is the implied "graceful degradation" it can allow. For example, loss of the bearing generation equipment should not affect pulse, scan, and frequency generators thereby allowing continued, even though incomplete, use of the system.

Look for modularity not only at the system level, but also at the device level. Easily replaceable circuit cards should significantly help to minimize mean-time-to-repair. (This assumes, of course, that one can financially afford to maintain a good library of cards, or that they can be purchased from/repaired by the manufacturer in minimal time.) But in all of this one cautionary note that should apply to any type of electronic system is: look for systems with simplicity of design, and an engineering approach to problems that applies current, but well proven state of the art. One does not want to buy into something nearly obsolete. But at the same time, be leery of systems wherein the engineering forces the state of the art to meet specifications. The result may be an exceptional piece of complex engineering mastery, but also one so unique that the customer becomes a captive to a particular manufacturer for parts and repair.

C. PROGRAMMABLE PARAMETERS/CHARACTERISTICS

With RF simulation, many of the characteristics important to signal generation were examined. Regardless of the type of simulation employed, one should seek a system having some or all of the following parameters programmable:

1. Signal Characteristics
   * RF frequency
   * RF power level
   * pulse width
   * pulse repetition frequency
   * pulse groups/coding
   * antenna scan type
   * antenna scan rate
   * DF capability - true and/or relative bearing

2. Platform Characteristics
   * range
   * heading
   * speed
   * turn rate

D. STUDENT-COMPUTER INTERACTION/RESPONSE

Instructor billets have been the target of personnel decrement action to at least an equal, if not greater, extent as all other DOD elements, this due to an armed force of reduced numbers. The net effect in training commands has been an increase in the student/instructor ratio with the inherent decrease in personalized instruction. To compensate for this shift, some training commands are turning to computer assisted/managed instruction (CAI/CMI).

In the ensemble, the intent of CAI/CMI is to direct a student's course of instruction with minimal instructor intervention through the use of computer algorithms which query the student, monitor and tabulate his response, indicate his errors and offer remedial queries/studies. Instructors are not eliminated from the teaching process as they still maintain a monitoring function wherein they can assist those students having extraordinary learning problems. What the system seeks to maintain is a reasonable student/instructor ratio by allowing instructors to direct their greatest efforts to those students who need it most. It also seeks to reduce/eliminate the tedious administrative chore of scoring student response by automatically tabulating results in computer memory for later hard-copy print out.

Although the Naval Training Center in Pensacola has only recently entered contractual discussions with Grumman Aerospace on the implementation of a large scale CAI/CMI EW trainer called the Naval Electronic Warfare Training System (NEWTS) this approach has already been explored to some extent by other manufacturers such as Antekna, Inc.

What might be the elements of student response in such a computerized system? (In reality this could apply to any system; you do not <u>have</u> <u>to</u> have a computer to query and tabulate - a pencil and paper can perform the same function on a more rudimentary basis.) The response should include much of what you are able to program in the form of signal parameters:

* response time
* emitter identification
* target bearing
* frequency
* pulse repetition frequency

* pulse width
* scan rate
* scan type

What types of corrective computer feedback might be available in a CAI/CMI system? One Antekna approach provides three types of corrective feedback at the student's learning station:

1. Immediate feedback, wherein the student's recorded measurements and deviation from actual parameter values are provided via CRT display.

2. Exercise interrupt, wherein an alarm indication is provided at any point in the exercise at which the student allows an unexpected lethal threat condition to exist.

3. Post exercise performance summaries, which can be CRT displayed and/or hard-copy printed for record purposes and which might include:
* average response time for threat signal identification
* number of early threat detections
* percentage of correct threat identifications
* average range/bearing error
* average error for each measurable parameter respectively.

E. DESIRABLE EW SCENARIO CHARACTERISTICS

A desirable scenario feature in a moderately sized EW simulator would be the capability to generate and execute long term (computer controlled) scenarios with the option to override during program execution. The long term characteristic is important if only for the fact that watch

standing periods can be four hours long or longer, or that many significant naval exercises are of considerable duration. Additionally, it may take a considerable amount of time to aclimate an operator to a simulated watch station environment so that he feels in effect that it is very much like "the real thing."

Implicit in the option-to-override feature is the capability to modify sections of the exercise or certain signal parameters either before or during program execution, to be able to freeze the scenario, or to selectively jump ahead or back without loss of simulation accuracy or time synchronism. Particularly important is this capability to change signal parameters or portions of the scenario, for several reasons: the transmitters that are being simulated may in reality have the capability to change parameters; operators repeating a particular exercise would be less inclined to be lulled into a sense of "having seen this before," if made aware that the exercise and/or signal parameters can be modified; having the capability to change an emitter's characteristics, say by introducing some incidental modulation could provide a method for training operators in platform-emitter correlation.

F. SIMPLIFIED PROGRAMMING FEATURES

The computer is a marvelous machine which can work wonders for man. But unless many personnel have easy access to, and control over, this tool, it becomes the exclusive domain of a smaller group of experts, namely the programmers. Although the Navy does have its programmers, in the interest of personnel efficiency and to promote a sense of control over even small scale simulators, it would seem highly desirous to make programming tasks simple enough that EW instructors could perform these functions on their own.

What programming features might be desirable to achieve this objective?

1. Emitter generation/signature composition via macroinstruction. We have already seen that several parameters must be combined to construct a desired signal. Rather than have to every time reconstruct a signal from its basic constituent parameters, this task could be simplified by the implementation of preset algorithms which would automatically call up the microinstructions associated with these parameters.

2. Usage of standard electronic terminology. Rather than requiring system operators to organize their thoughts into some complex format needed to converse with a computer, it would be highly desirous to allow parameter specification in standard terminology; e.g., beamwidths in degrees, sidelobe levels in decibels, ranges in nautical miles. The translation of these can be left to the computer so that the process is in effect transparent or invisible to the user. In both this area, and the one enumerated above, one should want a senior enlisted with no programming experience to be able to control/direct the functions of the training device and a junior trainee to be able to converse with the system in relatively simple and straightforward terms.

So far we have only discussed the topic of programming simplicity. What other program features might also be significant? In other sections of this report, the capability to override/change preprogrammed instructions has already been mentioned. Compatibility of programming equipments is also important. This would allow tapes made on one machine or at one location to be applied at many distant systems if necessary. The obvious solution of course is to have identical equipments at all locations, but this may not always be the case as system

improvements/modifications might alter programming features, or equipment interfaces may be costly to implement or plagued with incompatibility problems.

Although nearly implicit in the ability to create computer controlled scenarios, one should seek a capability to program test/calibration and maintenance tapes. Just as you can program to generate complex signals and scenarios, so should you be able to generate simple standards to act as a system check or reference. (This, of course, assumes that signal generators will remain stable and accurate over a long period of time - not a trivial assumption.)

G. DESIGN FEATURES TO MINIMIZE THE COMPLEXITY OF MAINTENANCE AND REPAIR TASKS

The following could help to minimize required maintenance and repair:

1. Modularization, which has already been discussed

2. Interchangeability of like components and subassemblies within the system/modules

3. Locating necessary adjustment points at the top edge of printed wiring assemblies where practical, to make it unnecessary to remove a board for test or place it on an extender board

4. Locating test points which monitor principal circuit functions at the edge of the circuit board.

Although the benefits/advantages of such features are obvious, they portend the advent of what one might call "module changers" or "black box specialists," wherein our

maintenance personnel become highly versed in trouble shooting and circuit board replacement on one particular equipment, but not terribly adept at actually correcting a circuit problem. Other problems which could arise because of such training emphasis: technicians familiar/comfortable with only one or two pieces of equipment may be hesitant or incapable of conducting allied/analogous repair tasks on other gear; and the cost in logistical support for maintaining an adequate supply of these modular circuit assemblies is not insignificant. Although it is true that many manufacturers do try to standardize basic subassemblies (e.g., making all power supplies the same for different modules), still one has to maintain a goodly number of these on board or face the prospect of doing without the circuit board while it is being returned to and/or being repaired by some central Navy repair facility or by the manufacturer himself. This of course may be no worse than having to search out/purchase the one faulty component on the board itself, but if our maintenance technicians are unable to go beyond the "isolate the bad card" sort of "repair," we could be facing serious operational difficulties in the future.

H. THOUGHTS ON THE SELECTION OF AN EW SIMULATOR

It is hoped that the information presented in this thesis has helped the reader gain some insight into the elements that make up this broad topic of electronic warfare simulation. It would be a bit presumptuous to prescribe a particular simulator for any given application, but in closing it might be well to reemphasize a few basic points that should be kept in mind during selection of a simulator.

What is the best kind of simulator? There probably is no absolute best simulator; the choice will depend on what it is one seeks to accomplish. If the only intent is to train operators, nearly the whole gamut of simulators could be applicable. The generic simulators such as NEWTS provide an excellent vehicle for teaching a broad range of basic intercept skills, whereas the more specialized training associated with an actual intercept receiver suite would probably be better accomplished with an RF stimulator.

With the severly limited instructor quotas DOD agencies must now live with, the use of some sort of computer assisted/managed instruction almost becomes a necessity. It need not be as elaborate as that proposed in the NEWTS; its implementation even on a small scale should result in a reduction of the time devoted to the correcting of basic errors committed by trainees.

If the simulator is to be used in the testing of new equipments, regardless of any possible training application, one of the modular and programmable RF stimulation type is probably the only appropriate one. In the area of design testing, this allows one to test individual components before final assembly as well as provide for overall system's test. An RF stimulator has the significant advantage of not being made obsolete by changes in current EW systems or the total replacement of these systems. Its modularity and programmability allows the expansion of capabilities along with changes in the EW world. The EW environment is a dynamic one. With time, usable frequency ranges are expected to go beyond 40 GHz, changes in tactics and delivery of weapons are apt to change. There are certain basic signal parameters that will not change, but how these parameters interrelate in any given signal or weapons system may very well change; new combinations of

parameters not seen today may exist tomorrow. The ability to adjust to this changing environment through the reprogramming of modular components, although initial programming costs may be high, may be the only realistic solution.

APPENDIX A

FIGURES

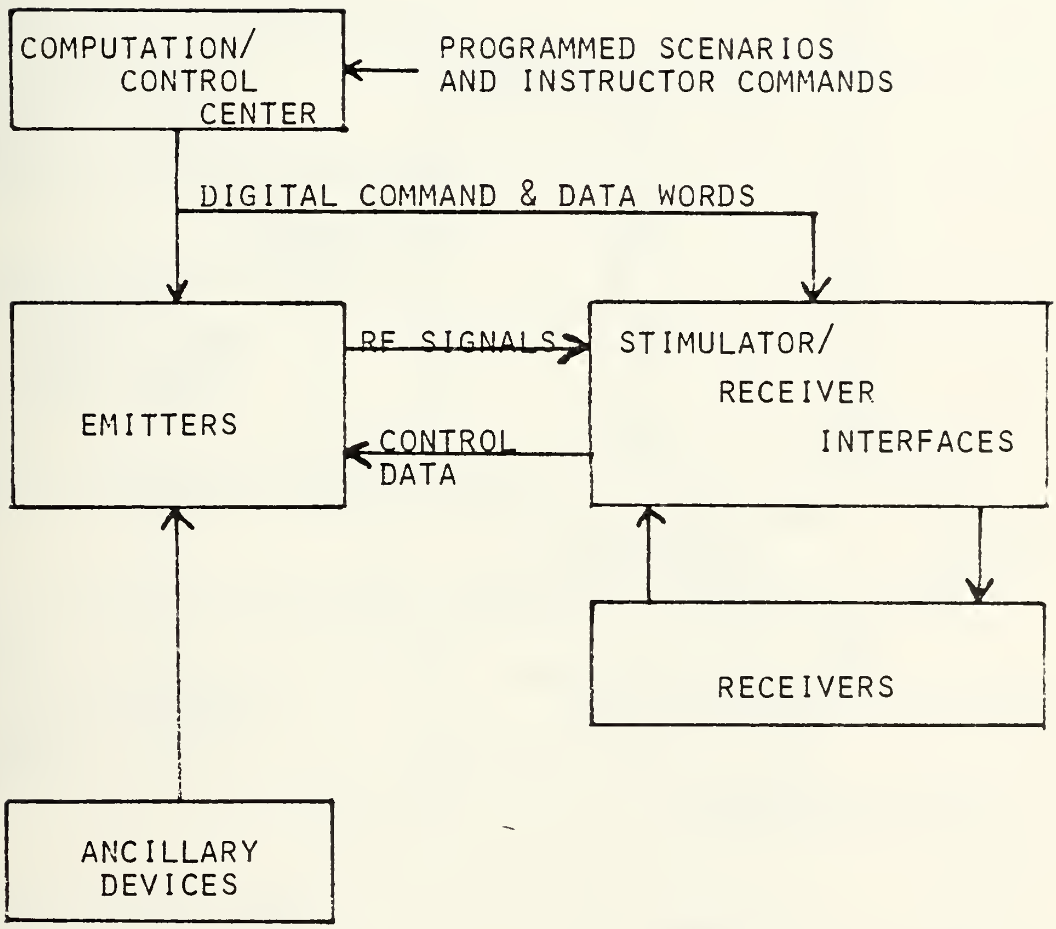

Figure 1 - 7B1/1 BLOCK DIAGRAM

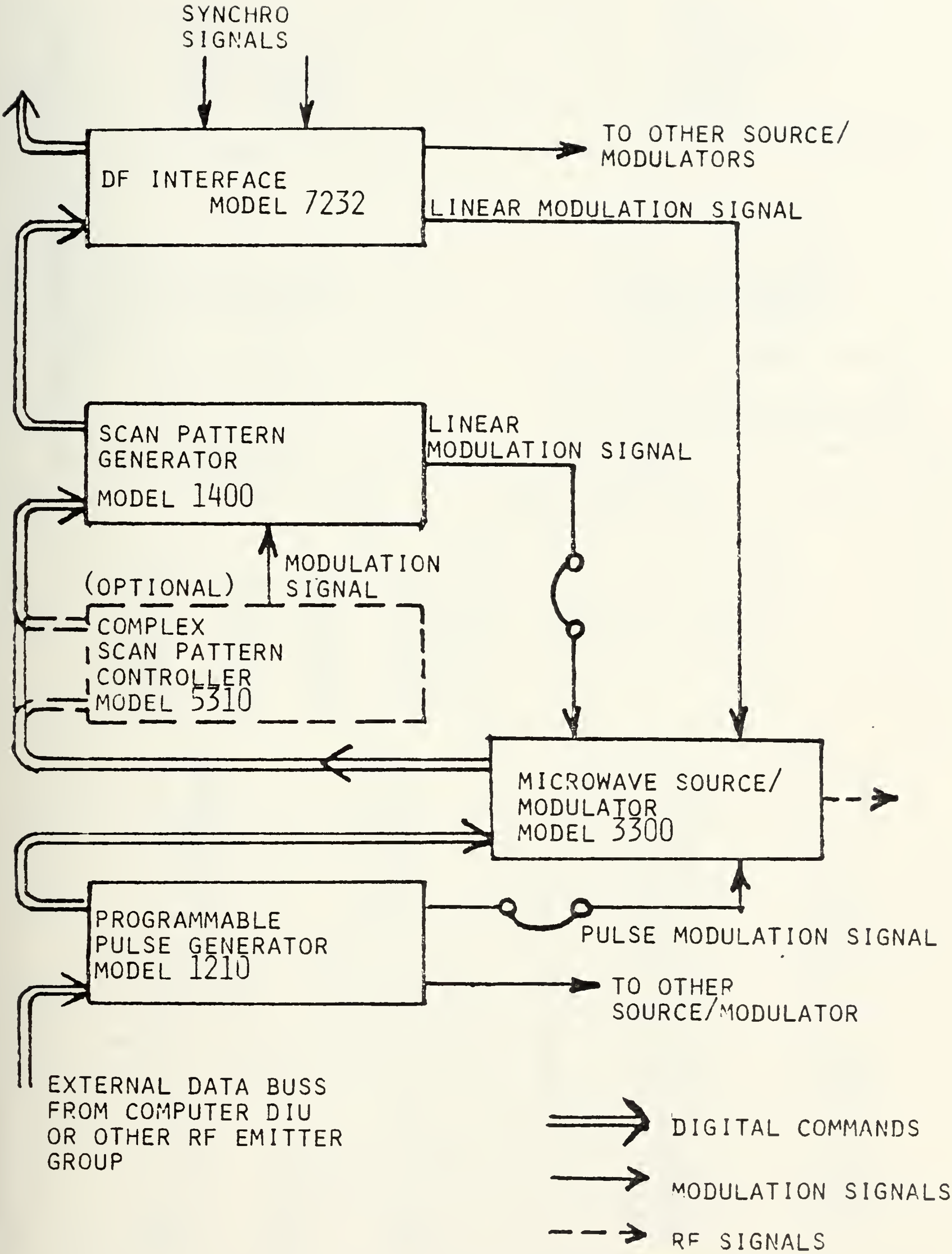

Figure 2 - RF EMITTER GROUP

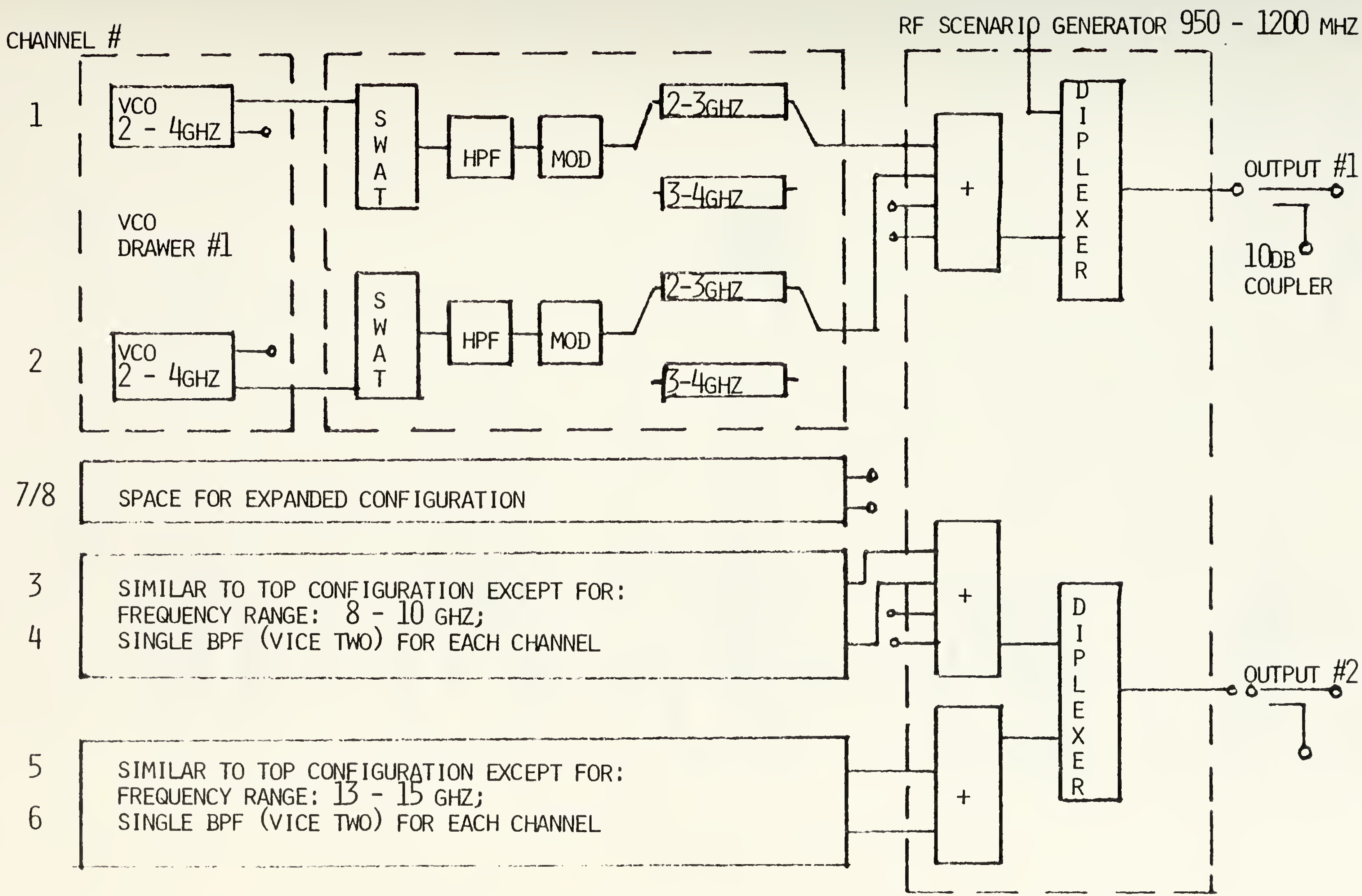

Figure 3 - ERTS RF BLOCK DIAGRAM

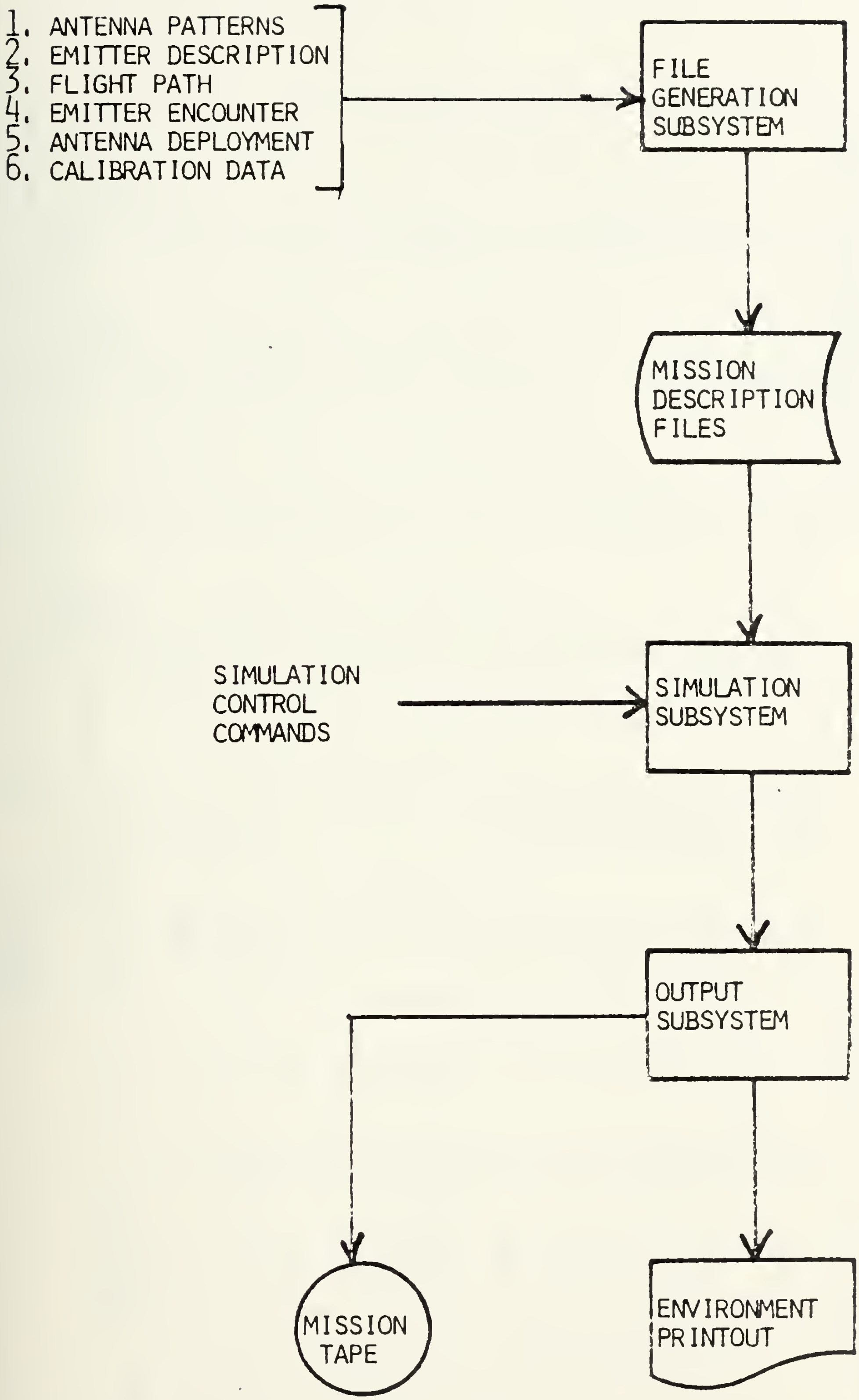

Figure 4 - ERTS SOFTWARE

			MODULATION SOURCE #	0 - 3	4 - 15	16 - 27	28 - 31	
			SOURCE TYPE / FREQ (MHZ)	EXTERNAL	MORSE CODE	TTY	VOICE	
BAND	EMITTER MODULE #	QTY					AM	FM
1	0 - 7	8	.01 - .15		X	X		
2	8 - 15	8	.19 - .50		X			
3	16 - 31	16	2. - 3.	X	X	X	X	
4	32 - 47	16	3. - 4.	X	X	X	X	
5	48 - 63	16	4. - 6.	X	X	X	X	
6	64 - 79	16	6. - 8.	X	X	X	X	
7	80 - 87	8	8. - 10.	X	X	X	X	
8	88 - 95	8	30. - 50.	X			X	X
9	96 - 111	16	100. - 150.	X			X	*
10	112 - 119	8	150. - 180.	X				X
11	120 - 127	8	300. - 400.	X			X	
# 3/7	128 - 131	4	2. - 10.	X	X	X	X	
# 9	132 - 135	4	100. - 150.	X			X	

#BACKGROUND SIGNAL GENERATORS

*ALSO PSEUDORANDOM PULSE WIDTH

Figure 5 - CRTS HARDWARE CONFIGURATION

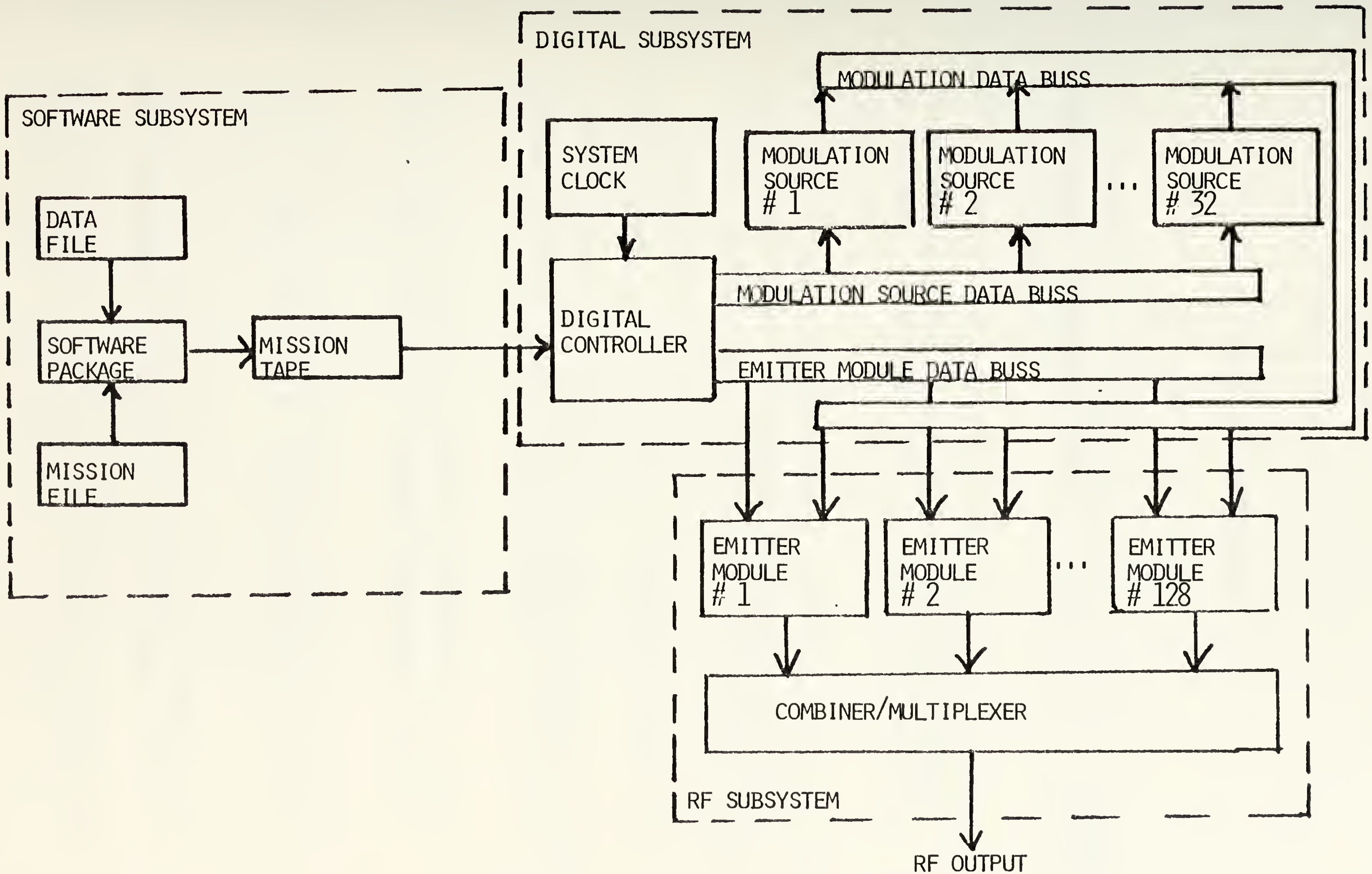

Figure 6 - CRTS BLOCK DIAGRAM

LIST OF REFERENCES

1. G.A. Bekey and D.L. Gerlough, "Simulation," In System Engineering Handbook, Robert E. Machol ed., McGraw-Hill Book Company, 1965.

2. M.A. Grodsky, "Man-Machine Simulation," In Prospects for Simulation and Simulators of Dynamic Systems, pp. 83-102, G. Shapiro and M. Rogers eds., Spartan Books, 1967.

3. R.W. Pew, "Human Information - Processing Concepts for System Engineers," In System Engineering Handbook, Robert E. Machol ed., McGraw-Hill Book Company, 1965.

4. J. DiGiovanni, "EW Training Simulation," Microwave Systems News, v. 1, no. 5, p. 3, May/June 1971.

5. Grumman Aerospace Corporation, Naval Electronic Warfare Training System, Device 10H1, Technical Description, 1976.

6. Antekna Incorporated, Technical Proposal for Device 10A3/3, ESM (Electronic Support Measures) Trainer, v. 1, December 1974.

7. Antekna Incorporated, Technical Proposal for Device 10A3/4, ECM (Electronic Countermeasures) Trainer, v. 2, December 1974.

8. Martin Marietta Corporation, Technical Proposal for ELINT Receiver Test System, v. 1, November 1975.

9. Martin Marietta Corporation, Technical Proposal for COMINT Receiver Test System, v. 2, November 1975.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
3.	Department Chairman, Code 62 Department of Electrical Engineering Naval Postgraduate School Monterey, California 93940	1
4.	Assoc Professor S. Jauregui, Code 62Ja Department of Electrical Engineering Naval Postgraduate School Monterey, California 93940	5
5.	LT Normand Arthur Houle, USN 161 Lake View Lane Manchester, New Hampshire 03104	1
6.	Commanding Officer, Code 10 Naval Submarine School Groton, Connecticutt 06340	1
7.	Commanding Officer, Code 310 Naval Technical Training Center Corry Station Pensacola, Florida 32511	1

8. Commanding Officer, Code 330 1
Naval Technical Training Center
Corry Station
Pensacola, Florida 32511

9. Commanding Officer, Code 06 1
Naval Electronics Systems Engineering Center
P.O. Box 80337
San Diego, California 92138

10. Commander, Naval Electronics Systems Command 1
PME-107
Washington, D.C. 20360

11. Commander, Naval Electronics Systems Command 5
PME-107-1
Washington, D.C. 20360

12. Commander, Naval Electronics Systems Command 2
PME-107-5
Washington, D.C. 20360

13. Commander, Naval Security Group Command 1
G-80
3801 Nebraska Ave., N.W.
Washington, D.C. 20390

14. Commander, Naval Security Group Command 1
G-82
3801 Nebraska Ave., N.W.
Washington, D.C. 20390

15. Commander, Naval Security Group Command 1
G-52
3801 Nebraska Ave., N.W.
Washington, D.C. 20390

16. Commander, Naval Security Group Command 1
G-10
3801 Nebraska Ave., N.W.
Washington, D.C. 20390

17. Director, National Security Agency 1
Chief W Group
Ft. George G. Meade, Maryland 20755

18. Thomas Milheiser 1
Martin Marietta Corporation
P.O. Box 179
Denver, Colorado 80201

19. Joseph DiGiovanni 1
Antekna Incorporated
625 Clyde Avenue
Mountain View, California 94040

Thesis 169745
H8163 Houle
c.1 Electronic warfare simulation as applied to passive intercept training.